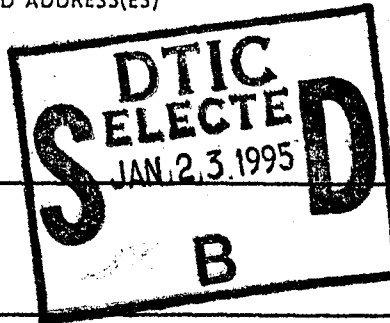


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Contract Number DAAK-11-83-D-007  
Task Order 0006

**ROCKY MOUNTAIN ARSENAL OFFPOST ASSESSMENT  
GROUND WATER QUALITY REPORT (CONSUMPTIVE USE-PHASE II)  
FOR SAMPLING PERIOD  
SEPTEMBER THROUGH OCTOBER 1985**

ENVIRONMENTAL SCIENCE AND ENGINEERING, INC.  
7332 South Alton Way, Suite H  
Englewood (Denver), Colorado 80112

August 1986

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Prepared for:

Office of Program Manager  
Aberdeen Proving Ground, Maryland 21010-5401

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TABLE OF CONTENTS

<u>Section</u>	<u>Page</u>
<b>1.0 INTRODUCTION AND BACKGROUND</b>	1-1
1.1 <u>STUDY AREA</u>	1-2
1.2 <u>HISTORICAL OVERVIEW</u>	1-5
1.3 <u>CONTAMINANTS OF CONCERN</u>	1-6
1.4 <u>GEOLOGY</u>	1-8
1.5 <u>GEOHYDROLOGY</u>	1-8
<b>2.0 SAMPLE PLAN DESIGN</b>	2-1
<b>3.0 FIELD VERIFICATION AND SAMPLING</b>	3-1
3.1 <u>CANDIDATE WELL VERIFICATION</u>	3-1
3.2 <u>UNSUITABLE WELLS</u>	3-1
3.3 <u>ALTERNATIVE WELLS</u>	3-1
3.4 <u>SAMPLING</u>	3-5
<b>4.0 FIELD PROCEDURES</b>	4-1
4.1 <u>SAMPLING CRITERIA</u>	4-1
4.2 <u>FIELD MEASUREMENTS AND SAMPLE COLLECTION</u>	4-2
4.3 <u>SAMPLE SHIPMENT</u>	4-3
4.4 <u>SAMPLE SPLITS</u>	4-4
<b>5.0 LABORATORY ANALYSIS</b>	5-1
<b>6.0 ANALYTICAL RESULTS</b>	6-1
<b>7.0 DISCUSSION</b>	7-1
7.1 <u>WATER QUALITY CRITERIA</u>	7-1
7.2 <u>DATA PRESENTATION</u>	7-1
7.3 <u>PHYSICAL/CHEMICAL CONTAMINANT PROPERTIES</u>	7-8
7.4 <u>CONTAMINATION DISTRIBUTION AND MIGRATION</u>	7-19
7.5 <u>COMPARISON OF PHASE I AND PHASE II RESULTS</u>	7-24
7.6 <u>SAMPLE SPLITS</u>	7-26
<b>BIBLIOGRAPHY</b>	
<b>APPENDIX A</b>	

### LIST OF FIGURES

<u>Figure</u>		<u>Page</u>
1.1-1	Phase I Study Area Boundaries	1-3
1.1-2	Relative Contaminant Levels-Study Area Phase I	1-4
1.4-1	Major Structural Elements of the Southern Rocky Mountains	1-9
1.4-2	Geologic Cross Sections	1-10
1.4-3	Generalized Composite Section of the Geologic Units of the Denver Basin	1-11
1.4-4	Geologic Map of the Rocky Mountain Arsenal Area	1-12
1.5-1	Denver Ground Water Basin	1-13
1.5-2	Upper Stratigraphic Sections of Denver Basin	1-15
1.5-3	Elevations of Bedrock Surface	1-18
1.5-4	Water Table Contour Map of Study Area	1-19
2.0-1	Contaminated Areas Offpost of Rocky Mountain Arsenal	2-2
3.1-1	Rocky Mountain Arsenal Offpost Field Data Sheet	3-2
7.2-1	Water Quality in Alluvial Wells	7-7
7.2-2	DIMP Assessment in Alluvial Wells	7-9
7.2-3	DCPD Assessment in Alluvial Wells	7-10
7.2-4	Chlorinated Pesticide Assessment in Alluvial Wells	7-11
7.2-5	Aromatic and Halogenated Aliphatic Solvent Assessment in Alluvial Wells	7-12
7.2-6	Chloride Assessment in Alluvial Wells	7-13
7.2-7	Fluoride Assessment in Alluvial Wells	7-14
7.2-8	Fluoride Assessment in Bedrock Wells	7-15
7.4-1	Inferred Locations of Bedrock Surface Paleochannels	7-20

# LIST OF TABLES

<u>Table</u>		<u>Page</u>
3.2-1	Wells Found to be Unsuitable for Sampling	3-4
3.3-1	Alternative Wells	3-6
3.4-1	Wells Sampled During the Phase II Consumptive Use Ground Water Sampling Program	3-7
4.4-1	RMA Phase II Consumptive Use Sampling Sample Splits	4-5
5.0-1	Chemical Analysis--Offpost Study Area	5-2
5.0-2	Revised Detection Limits-- Phase II Consumptive Use Sampling	5-3
7.1-1	Water Chemistry Parameter Guidance Levels and Supporting Information	7-2
7.2-1	Water Quality Summary of Analytical Results--Number of Positive Results Among 40 Well Samples Analyzed	7-3
7.2-2	Water Quality Summary of Analytical Results by Well Usage--Organic Contaminants	7-5
7.3-1	Physical/Chemical Properties of RMA Migrating Contaminants	7-17
7.5-1	Comparison of Phase I and II Consumptive Use Sampling Program Data for Wells OTH-23 and OTH-5	7-25
7.6-1	Comparison of DIMP Analytical Results from Corresponding ESE, Shell, CDH, EPA, and SACWSD Sample Splits	7-27
7.6-2	Comparison of DBCP Analytical Results from Corresponding ESE, Shell, CDH, and EPA Sample Splits	7-28
7.6-3	Comparison of Aldrin Analytical Results from Corresponding ESE, Shell, and EPA Sample Splits	7-29
7.6-4	Comparison of Dieldrin Analytical Results from Corresponding ESE, Shell, and EPA Sample Splits	7-30
7.6-5	Comparison of Fluoride Analytical Results from Corresponding ESE, EPA, and SACWSD Sample Splits	7-31
7.6-6	Comparison of Chloride Analytical Results from Corresponding ESE, EPA, and SACWSD Sample Splits	7-32
7.6-7	Detection Limits and Number of Analyses for Corresponding ESE, Shell, EPA, and SACWSD Determinations Where No Analytes Were Detected	7-33

**LIST OF PLATES**

Plate

Page

1

Phase II Consumptive Use Well Locations

Pocket

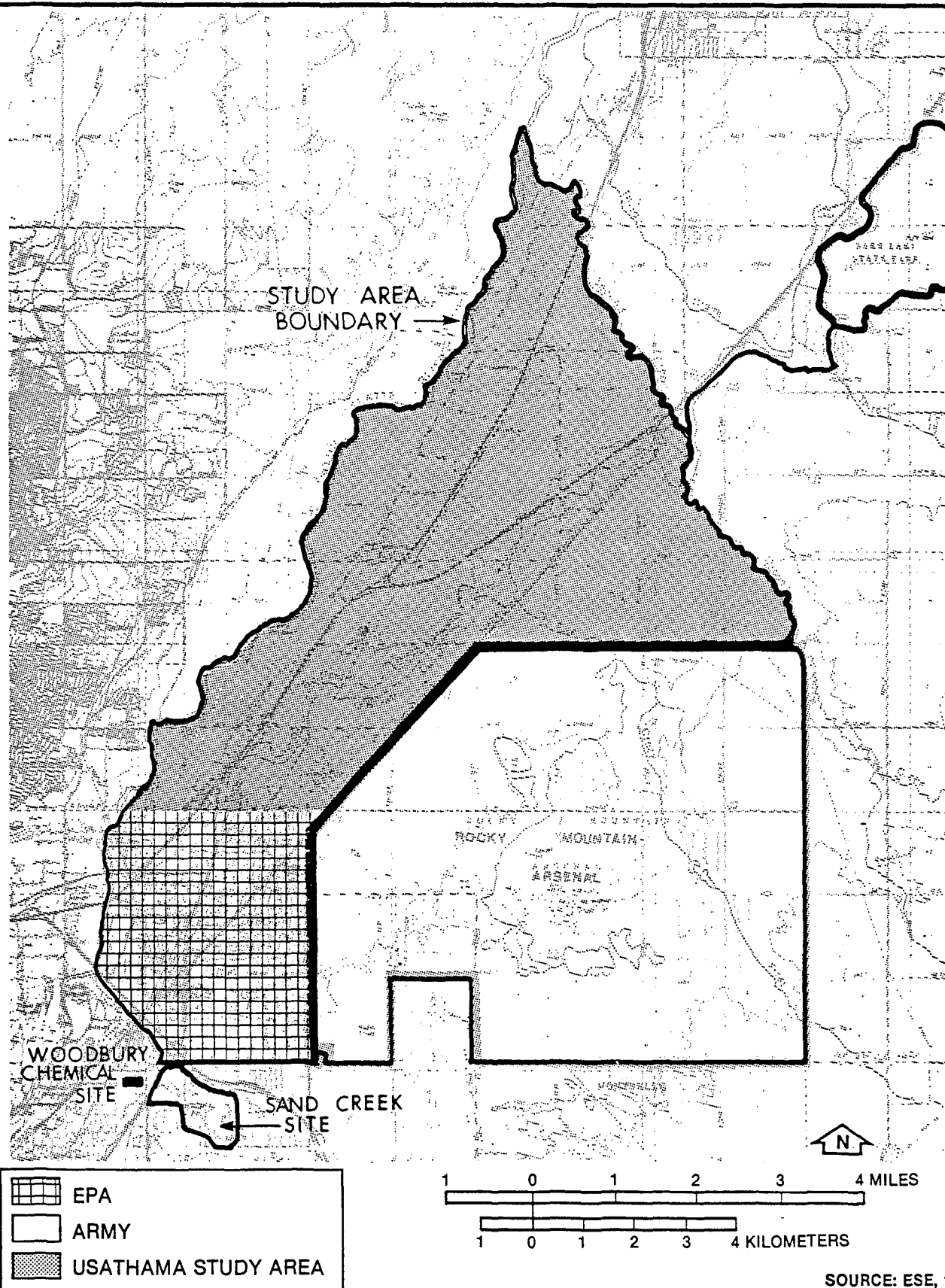
LIST OF ACRONYMS  
(Page 1 of 2)

CDH	Colorado Department of Health
CDM	Camp, Dresser & McKee, Inc.
CDWR	Colorado Division of Water Resources
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CF&I	Colorado Fuel and Iron Corporation
cm	centimeters
COE	U.S. Army Corps of Engineers
°C	degrees celsius
DBCP	dibromochloropropane
DCPD	dicyclopentadiene
DDT	dichlorodiphenyltrichloroethane
DIMP	diisopropylmethylphosphonate
DMMP	dimethylmethylphosphonate
DOD	U.S. Department of Defense
EPA	U.S. Environmental Protection Agency
ESE	Environmental Science and Engineering, Inc.
ft	feet
ha	hectares
HRS	HRS Water Consultants, Inc.
in	inch
km	kilometers
m	meter
MER	Master Extract Register
mg/l	milligrams per liter



LIST OF ACRONYMS  
(Page 2 Of 2)

MOA	Memorandum of Agreement
NCP	National Contingency Plan
PCPMS	p-chlorophenylmethyisulfide
PCPMSO	p-chlorophenylmethyisulfoxide
PCPMSO <sub>2</sub>	p-chlorophenylmethyisulfone
PM-CDIR	Project Manager Chemical Militarization Installation Restoration
ppb	parts-per-billion
PVC	polyvinyl chloride
QA	Quality Assurance
QC	Quality Control
RMA	Rocky Mountain Arsenal
SACWSD	South Adams County Water and Sanitation District
Shell	Shell Chemical Company
TCDHD	Tri-County District Health Department
USATHAMA	U.S. Army Toxic and Hazardous Materials Agency
µg/l	micrograms per liter
µmho/cm	micromhos per centimeter
USPLS	U.S. Public Land Service
WES	Waterways Experiment Station
WWII	World War II
<	less than



SOURCE: ESE, 1984

Figure 1.1-1  
PHASE I STUDY AREA BOUNDARIES

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For Rocky Mountain Arsenal  
Aberdeen Proving Ground, Maryland

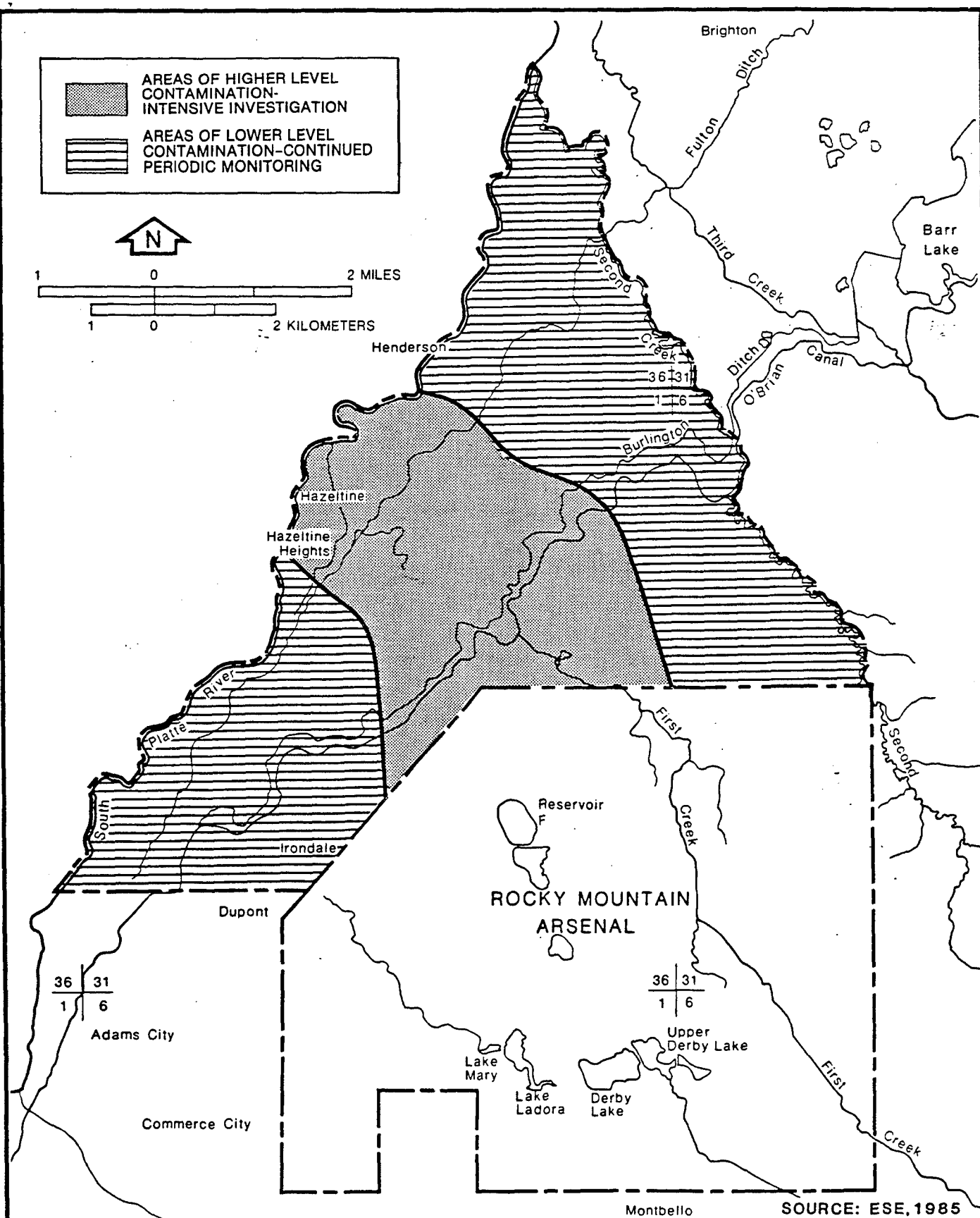


Figure 1.1-2  
RELATIVE CONTAMINANT LEVELS  
STUDY AREA PHASE I

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further define the area boundaries and delineate probable contaminant plumes.

Land use within this Phase II study area is primarily used for agricultural purposes, including livestock, vegetable, and grain farming. There is some industry located along East 104th Avenue in Sections 10 and 15 as well as along Brighton Boulevard in Section 3. Rural residences are scattered throughout the study area with the highest concentration occurring along Brighton Boulevard.

## 1.2 HISTORICAL OVERVIEW

RMA occupies over 6,880 hectares (ha) of Adams County, Colorado, and is located approximately 14 to 16 kilometers (km) northeast of downtown Denver.

The property occupied by RMA was purchased by the government in 1942. Throughout World War II (WWII), RMA manufactured and assembled chemical intermediate and toxic end-item products and incendiary munitions.

During the period 1945 to 1950, RMA distilled available stocks of Levinstein mustard, demilitarized several million rounds of mustard-filled shells, and test-fired 10.7 centimeter (cm) mortar rounds filled with smoke and high explosives. Also, many different types of obsolete WWII ordnance were destroyed by detonation or burning.

In 1947, certain portions of RMA were leased to the Colorado Fuel and Iron Corporation (CF&I) for chemical manufacturing. CF&I manufactured chlorinated benzenes and dichlorodiphenyltrichloroethane (DDT). Julius Hyman and Company assumed the CF&I lease in 1950 and produced several pesticides. Shell later assumed the pesticide and herbicide manufacturing operations.

Later, RMA was selected as the site for construction of a facility to produce chemical agent. This facility was completed in 1953, with the manufacturing operation continuing until 1957, and the munitions filling

operations continuing until late 1969. Since 1970, RMA has been involved primarily with the disposal of chemical warfare material.

### 1.3 CONTAMINANTS OF CONCERN

Presented below is a listing of the compounds and chemical species that have been identified as ground water contaminants on RMA by the U.S. Army Corps of Engineers (COE) Waterways Experiment Station (WES) (Spaine et al., 1983).

- o Volatile Organics;
- o Chlorinated Pesticides (aldrin, dieldrin, endrin, isodrin);
- o Dibromochloropropane (DBCP);
- o Diisopropylmethylphosphonate (DIMP);
- o Dimethylmethylphosphonate (DMMP);
- o Dicyclopentadiene (DCPD);
- o Chloride;
- o Fluoride;
- o 1,4-Dithiane/1,4-Oxathiane; and
- o p-Chlorophenylmethyl Sulfone (PCPMSO<sub>2</sub>)/ Sulfoxide (PCPMSO)/ Sulfide (PCPMS).

This Phase II water quality report will focus on the offpost identification of these contaminants in alluvial ground water. A brief discussion of these contaminants is presented below.

#### Volatile Organics

These compounds have only recently been quantified at RMA and little or no historical data are available on their distribution. Reportable concentrations of toluene, xylene, benzene, chlorobenzene, chloroform, carbon tetrachloride, dichloroethylene, trichloroethylene, and tetrachloroethylene have been identified. Because these compounds represent organic solvents in widespread industrial use, they cannot be identified as unique to RMA.

#### Chlorinated Pesticides

Chlorinated pesticides (aldrin, dieldrin, endrin, isodrin) have in the past been available for public use, but were later banned by the EPA

because of their hazardous nature. These chemicals were manufactured on RMA by a lessee.

#### DBCP

DBCP, or Nemagon, is a pesticide that was manufactured on the Arsenal by a lessee.

#### DIMP/DMMP

DIMP is unique to RMA since it is a by-product of the manufacture of a chemical agent. Process wastes were disposed of in the basins at RMA. The degradation product of DIMP is DMMP.

#### DCPD

DCPD is a raw material that was used by a lessee for pesticide production in the South Plants.

#### Chloride

Very high chloride concentrations in the ground water at RMA have been a contamination problem for many years. Large amounts of brine and salts containing chloride have been disposed of at RMA. Concentrations found in the ground water are often in excess of the natural concentration found in the area.

#### Fluoride

Although fluoride occurs naturally in the ground water in the Denver area, the concentrations of fluoride identified in some areas of the arsenal appear higher than the background levels. Fluoride in the form of hydrofluoric acid was used in the manufacture of chemical agent. Fluoride levels in the Lower Denver and Arapahoe Formations are naturally high and therefore levels above guidance in these formations may not be indicative of contamination.

#### 1,4 Dithiane/1,4-Oxathiane

Dithiane and oxathiane, compounds unique to RMA operations, are associated with the degradation of mustard gas. Neither of these compounds were detected in appreciable amounts during the Phase I

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investigation; therefore, samples collected during this study were not analyzed for these compounds.

#### PCPMSO<sub>2</sub>/PCPMSO/PCPMS

PCPMSO<sub>2</sub>, PCPMSO, and PCPMS are chemicals associated with tenant herbicide manufacturing operations. None of the wells sampled during the Phase I investigation revealed detectable amounts of these compounds, therefore Phase II samples were not analyzed for them.

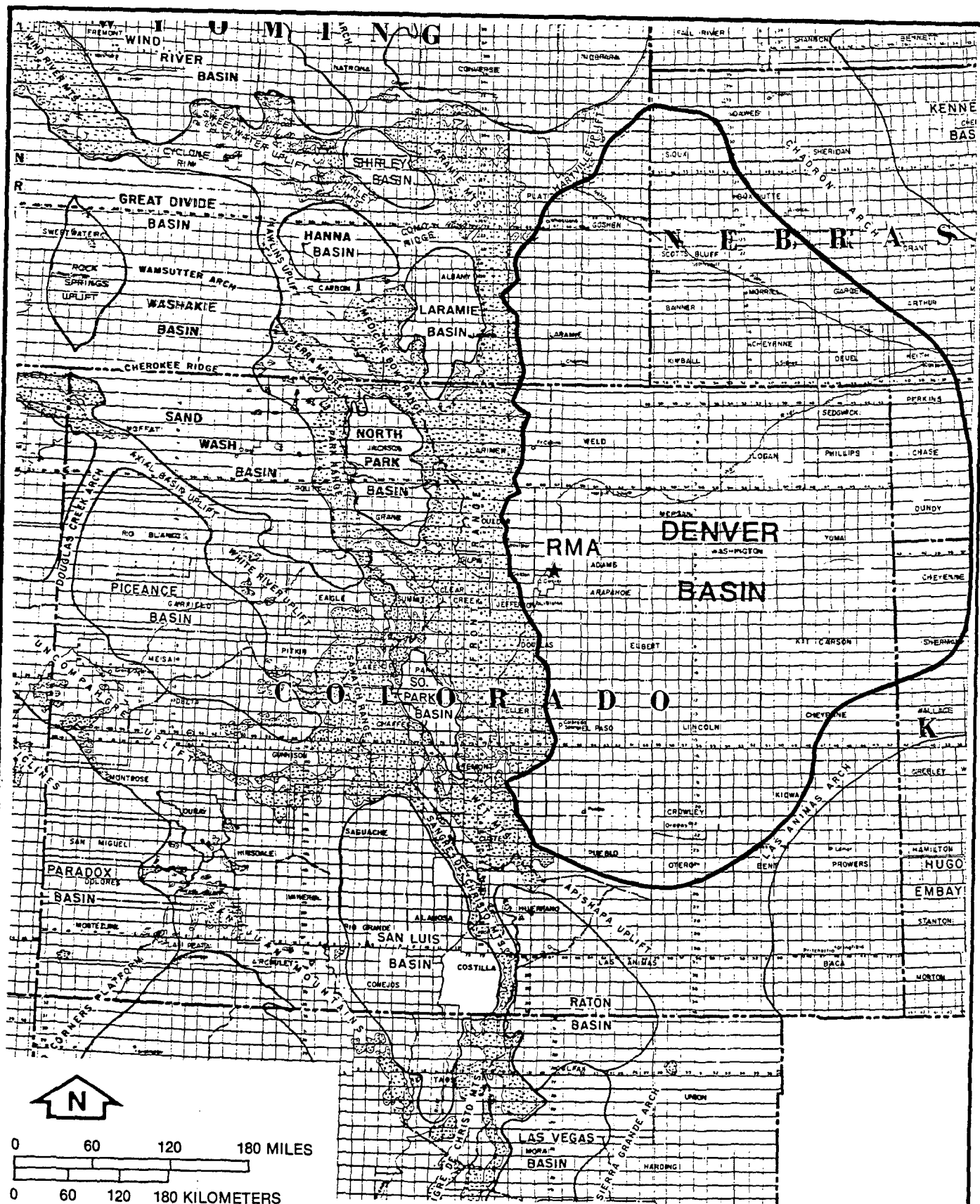
#### 1.4 GEOLOGY

The RMA offpost study area is located within the geologic province of the Denver Basin, a structural depression resulting from tectonic adjustments which occurred intermittently throughout time (Figure 1.4-1). The basin exhibits an elongate, north-south trending surface expression 500 km long by 300 km wide and occupies some 15,000,000 ha in north-central Colorado, Wyoming and Nebraska. Sedimentary strata composed of conglomerate, sandstone, shale and limestone lithologies rest on the Precambrian crystalline basement and fill the synclinal structure (Figure 1.4-2). Strata range in age from Cambrian to Quaternary (Figure 1.4-3).

The study area lies on a bedrock surface formed by the late Cretaceous-early Tertiary Denver Formation. Quaternary alluvial and eolian deposits crop out at the surface, overlying the Denver Formation (Figure 1.4-4). Regional dip is to the southeast.

#### 1.5 GEOHYDROLOGY

Ground water resources within the RMA offpost study area are classified as part of the Denver ground water basin. As illustrated in Figure 1.5-1, the basin underlies the area extending from Greeley, Colorado in the north to Colorado Springs, Colorado in the south and from the Front Range Uplift on the west to near Limon, Colorado in the east. Formations ranging in age from Pennsylvanian to Tertiary contain water bearing units. The four major bedrock aquifers are the Laramie-Fox Hills, the Arapahoe, the Denver, and the Dawson. Surficial deposits as well as the crystalline rocks of the Front Range locally yield sufficient quantities of water to be considered aquifers.

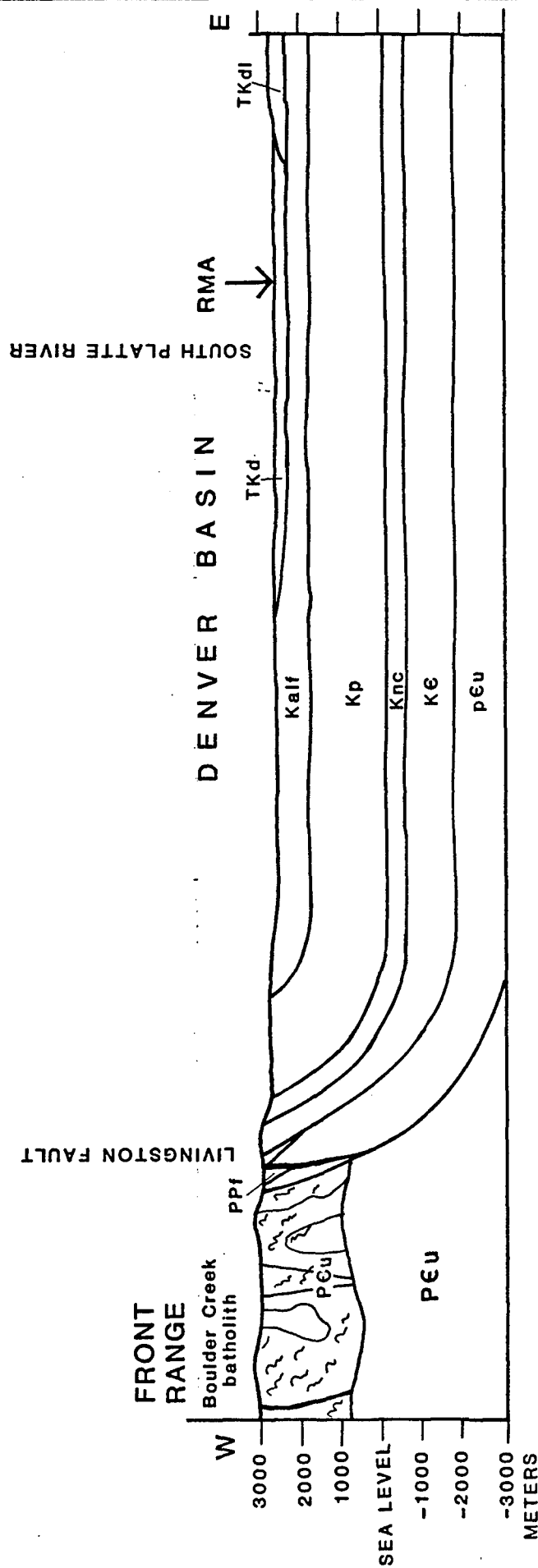


SOURCE: RMAG, 1972

Figure 1.4-1  
MAJOR STRUCTURAL ELEMENTS OF  
THE SOUTHERN ROCKY MOUNTAINS

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U.S. Army Program Manager's Office  
For Rocky Mountain Arsenal  
Aberdeen Proving Ground, Maryland





- TKdl DAWSON ARKOSE (TERTIARY - UPPER CRETACEOUS)
- TKd DENVER FORMATION (TERTIARY - UPPER CRETACEOUS)
- Kalf ARAPAHOE FORMATION, LARAMIE FORMATION, FOX HILLS SANDSTONE (UPPERCRETACEOUS)
- Kp PIERRE SHALE (UPPER CRETACEOUS)
- Knc NIOGRARA FORMATION, CARLILE SHALE, GREENHORN LIMESTONE, GRANEROS SHALE, (UPPER CRETACEOUS)
- KE DAKOTA SANDSTONE(UPPER CRETACEOUS) AND UNDERLYING MESOZOIC PALEOZOIC ROCKS
- PPf FOUNTAIN FORMATION (PERMIAN - PENNSYLVANIAN)
- pEu PRECAMBRIAN UNDIFFERENTIATED

SOURCE: USGS, 1981

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Figure 1.4-2  
 GEOLOGIC CROSS SECTION

Era	System or Period	Series	Geologic Unit	
Cenozoic	Quaternary	Recent and Pleistocene	<b>Quaternary surficial deposits</b>	Stream channel, flood-plain and terrace deposits; eolian sand, etc.
	Tertiary	Oligocene	Castle Rock Conglomerate	
			Tertiary intrusive and extrusive rocks	
Cenozoic and Mesozoic	Tertiary and Cretaceous	Paleocene —?— Upper Cretaceous	Dawson Group	<b>Dawson Arkose</b> <b>Denver Formation</b> <b>Arapahoe Formation</b>
Mesozoic	Cretaceous	Upper Cretaceous	Laramie Formation	Upper part <b>B sandstone</b> <b>A sandstone</b> <b>Milliken Sandstone</b> lower part
			Fox Hills Sandstone	
			Pierre Formation	
			Niobrara Formation	Smoky Hill Shale Fort Hayes Limestone Carlile Shale
		Lower Cretaceous	Brenton Formation	Greenhorn Limestone Graneros Shale
			Dakota Group	<b>South Platte Formation</b>
				<b>Lytle Formation</b>
	Jurassic	Upper Jurassic	Morrison Formation	
			Ralston Creek Formation	
Paleozoic	Triassic and Permian		Lykins Formation	Strain Shale Glennon Limestone Bergan Shale Falcon Limestone Harriman Shale
	Permian		<b>Lyons Sandstone</b>	
	Pennsylvanian		<b>Fountain Formation</b>	
			Glen Eyrie Formation	
	Mississippian		Madison Limestone	
			Williams Canyon Limestone	
	Ordovician and Cambrian		Manitou Dolomite	
	Cambrian		Sawatch Sandstone	
Precambrian			crystalline rocks	

Principal Aquifers in Boldface Type

Figure 1.4-3  
GENERALIZED COMPOSITE SECTION  
OF THE GEOLOGIC UNITS OF  
THE DENVER BASIN

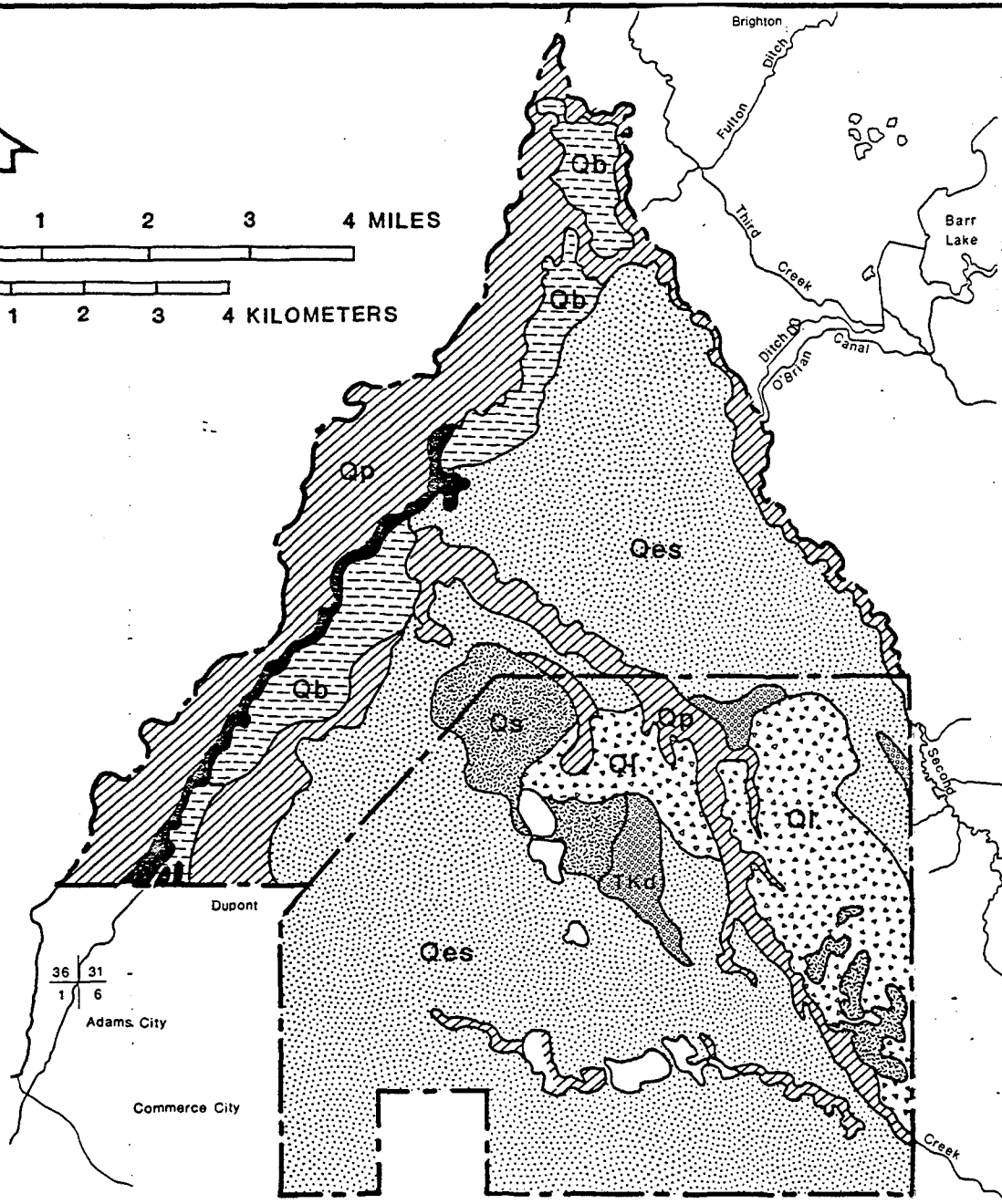
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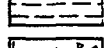
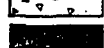





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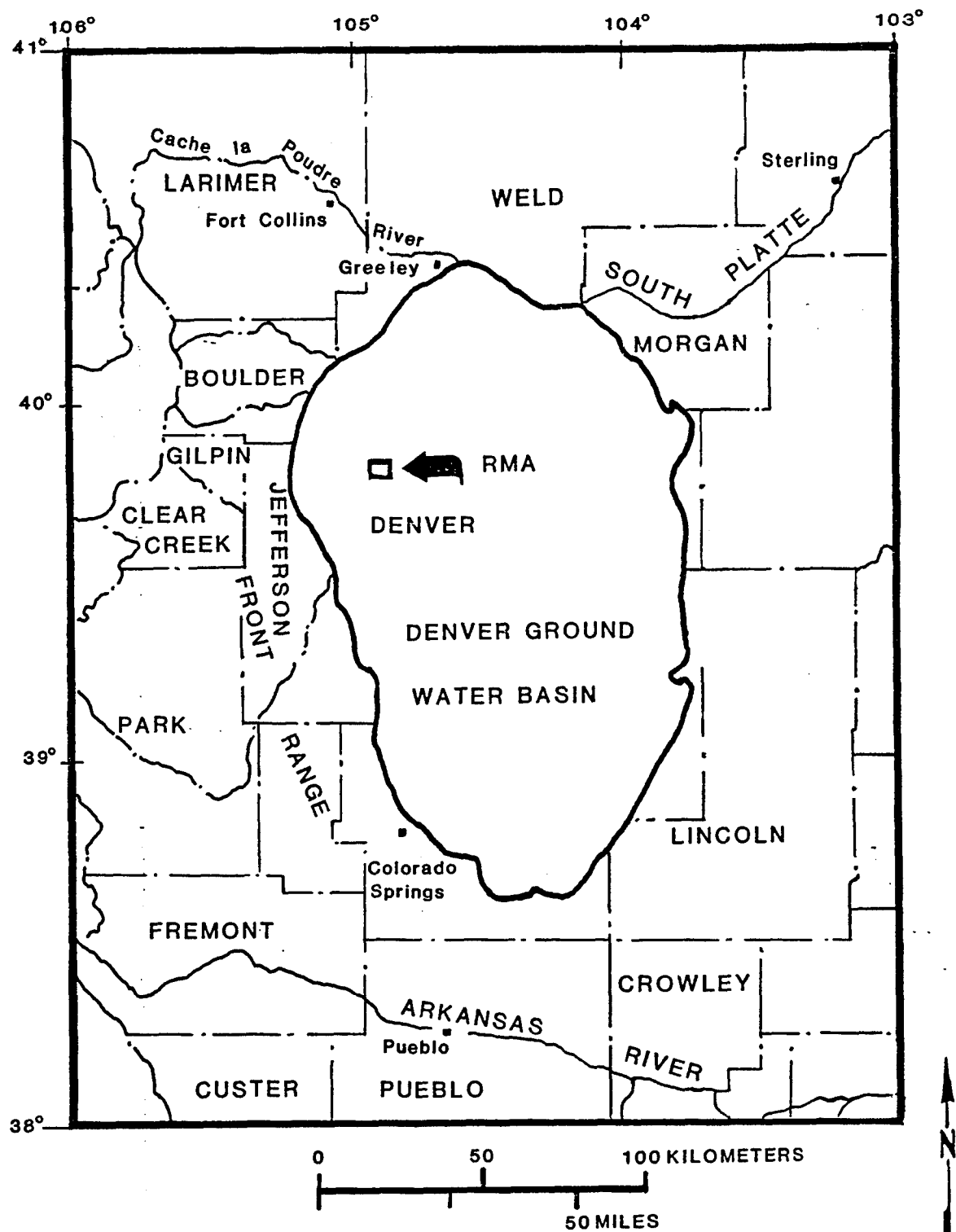


-  Qp POST PINEY CREEK ALLUVIUM (QUATERNARY)
-  Qes EOLIAN SAND (QUATERNARY)
-  Qb BROADWAY ALLUVIAL (QUATERNARY)
-  Qi LOESS (QUATERNARY)
-  Qlo LOUVIERS ALLUVIUM (QUATERNARY)
-  Qs SLOCUM ALLUVIUM (QUATERNARY)
-  TKd DENVER FORMATION (TERTIARY & UPPER CRETACEOUS)

SOURCE: USGS, 1981

Figure 1.4-4  
GEOLOGIC MAP OF RMA AREA

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SOURCE: ROBSON, 1981

Figure 1.5-1  
DENVER GROUND WATER BASIN

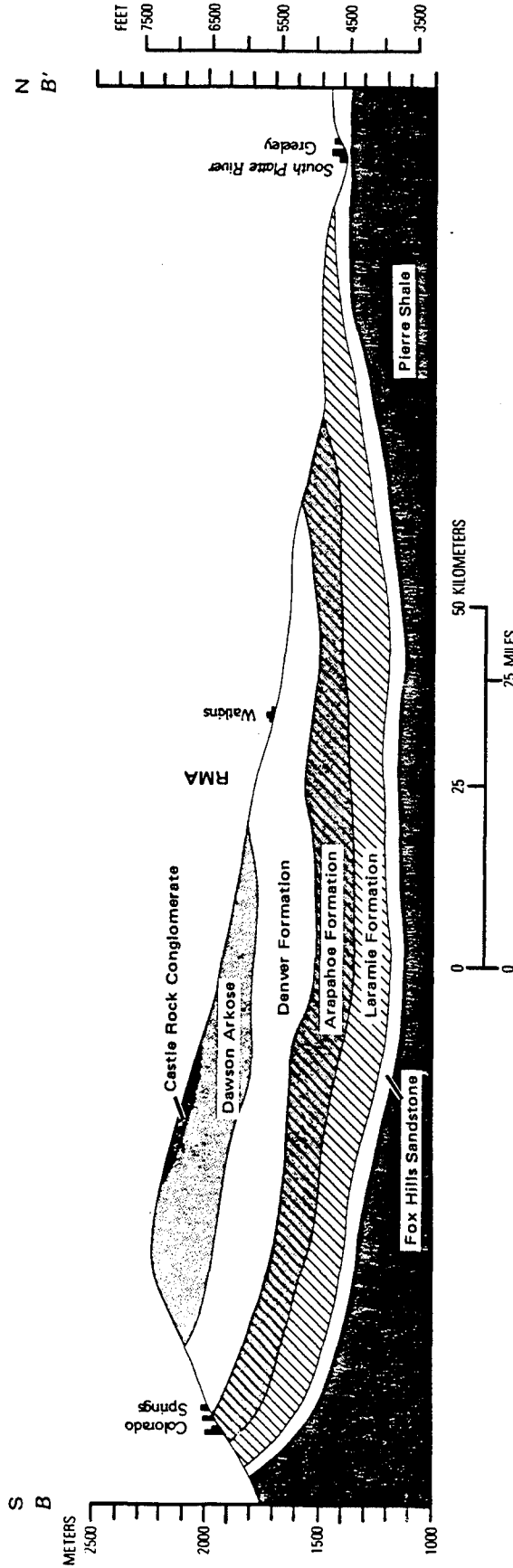
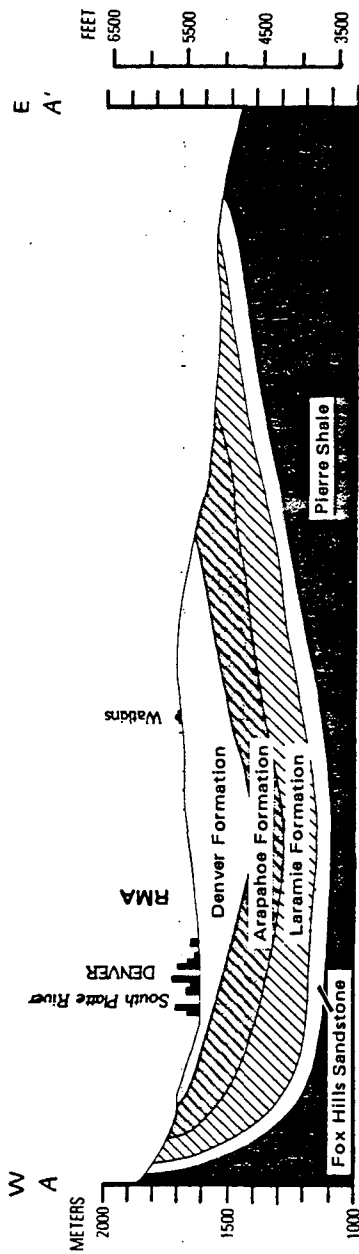
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For Rocky Mountain Arsenal  
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The geologic formations comprising the four major bedrock aquifers are the Fox Hills Sandstone and the Laramie and Arapahoe Formations of late Cretaceous age, the Denver Formation of late Cretaceous and early Tertiary age, and the Dawson Arkose of Tertiary age (Romero, 1976). These formations occur in a sequence of layers as shown by the generalized geologic sections drawn from west to east and from south to north through the basin (Figure 1.5-2). The northern, eastern and southern parts of the basin form a shallow bowl, the sides of which dip gently toward the west-central part of the basin. Along the western edge of the basin, sedimentary formations are upturned against the Precambrian crystalline rocks of the Front Range and dip steeply to the east as a result of faulting and the gradual upward movement of the Rocky Mountains. The Pierre Shale of late Cretaceous age underlies the Fox Hills Sandstone and is considered to be the base of the major bedrock-aquifer system due to its great thickness [as much as 2,400 feet (ft)] and its minimal permeability (Robson and Romero, 1981).

The strata of primary concern in the RMA offpost study area are the Arapahoe Formation, the Denver Formation, and the unconsolidated Quaternary alluvial and eolian surficial deposits. Aquifers within these units comprise the ground water regime in the study area.

#### Arapahoe Formation

The Arapahoe Formation is a 122 to 213 meter (m) thick sequence of interbedded conglomerate, sandstone, siltstone, and shale. The formation can be divided into two parts. Sandstone and conglomerate with thin beds of shale characterize the lower portion, while a predominantly blue to gray shale with minor lenses of sandstone and ironstone concretions marks the upper. The conglomerates, sandstones, and siltstones range from white to medium grey with some local yellow/green beds. Shales are commonly silty. The larger proportion of conglomerate and sandstone with respect to shale, absence of significant carbonaceous materials, and an overall lighter color distinguish the Arapahoe from the overlying Denver Formation.



SOURCE: ROBSON, 1981

Figure 1.5-2  
UPPER STRATIGRAPHIC SECTIONS OF DENVER BASIN

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Aberdeen Proving Ground, Maryland

Individual conglomerate and sandstone beds in the Arapahoe Formation are commonly lens shaped and range in thickness from a few centimeters to 9 or 12 m. The beds may be so closely spaced that they form a single hydrologic unit that is 60 to 90 m thick in some areas. The conglomerate and sandstone are generally only moderately consolidated and are much more coarse grained than the siltstone and shale. This allows ground water to flow through the void spaces between grains of gravel and sand in the conglomerate and sandstone, while little or no water is able to flow through the siltstone and shale (Robson, Romero and Zawistowski, 1981)

#### Denver Formation

The Denver Formation unconformably overlies the Arapahoe Formation and consists of 70 to 120 m of olive, bluish gray, green gray, and brown clay, shale, and siltstone interbedded with poorly sorted, weakly lithified tan to brown, fine to medium grained, lenticular sandstone and conglomerate. Lignite beds and carbonaceous shales are common, as are volcanic fragments and tuffaceous materials to a lesser degree. Minor beds of bentonite may also be present. The predominant olive and green-gray colors resulting from erosion and weathering of andesitic and basaltic lavas help distinguish the formation from the underlying lighter-colored Arapahoe Formation.

Water bearing zones in the formation are restricted to sandstone lithologies that are lenticular in nature. The lenses are irregularly distributed within thick clay-shale sequences. They are discontinuous and therefore difficult to trace, and are poorly defined where the sandstones grade into the encompassing clay and shale. The sandstone lenses range in thickness from a few centimeters to as much as 20 m. Ground water flow occurs within void spaces between the coarser sand grains in the sandstones, while little water is able to flow through the finer silt and mud components of the clay and shale.

#### Surficial Deposits

Sediments present at the land surface consist of unconsolidated alluvial and eolian deposits of Quaternary age. The material is composed

primarily of valley fill, dune sand, and terrace gravel which contain cobbles, boulders, and beds of volcanic ash as well as sands, gravels, silts, and clays. Combined thickness of the surficial materials ranges from 10 to 40 m. The thicker deposits represent filling of paleochannels cut in the surface of the Denver Formation. A structure contour map constructed on the top of the bedrock surface delineates these paleochannel depressions (Figure 1.5-3). Lithologic logs in the intrachannel areas indicate anomalously thick sequences of overburden drilled before penetrating the Denver. Colors range from yellow-brown to pale orange and are indicative of oxidation. Locally, deposits may be consolidated where calcium carbonate has cemented sands and gravels to form conglomerates.

The entire sequence of surficial materials should be considered capable of bearing water. Overall permeability of the deposit is enhanced by the coarse nature of the materials, especially in the paleochannels where the bulk of the basal fill consists of gravels, cobbles, and boulders. Paleochannels are likely to serve as the major alluvial ground water transport pathways in the study area.

The ground water regime in the offpost area is relatively complex due to the unique hydrologic, stratigraphic, and topographic relationships between the Arapahoe and Denver Formations and the overlying surficial deposits. A water table contour map for the alluvial aquifer is presented in Figure 1.5-4. Ground water in an isotropic aquifer will flow perpendicular to hydraulic contours from areas of high potentiometric or water table elevation to areas of low potentiometric or water table elevation.

The alluvial, Denver, and Arapahoe aquifers are partially isolated from each other by semi-permeable confining layers which restrict flow between the more permeable strata. Flow between the more permeable strata occurs where confining beds are absent, creating interconnections between aquifers. Similar interconnections can be provided by improperly constructed or corroded ground water wells. Improperly sealed well casings can allow ground water to flow vertically through confining



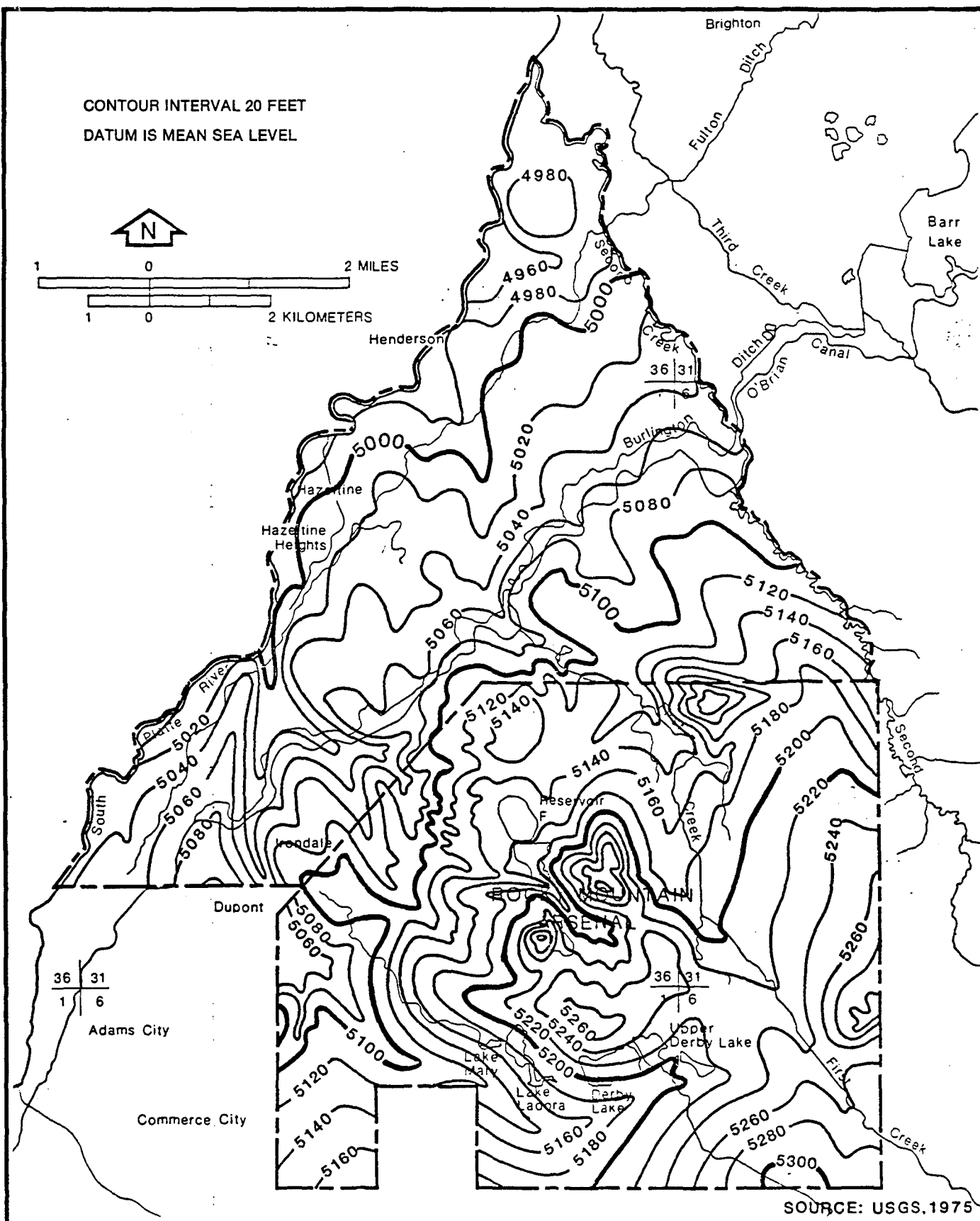


Figure 1.5-3  
ELEVATIONS OF BEDROCK SURFACE

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For Rocky Mountain Arsenal  
Aberdeen Proving Ground, Maryland

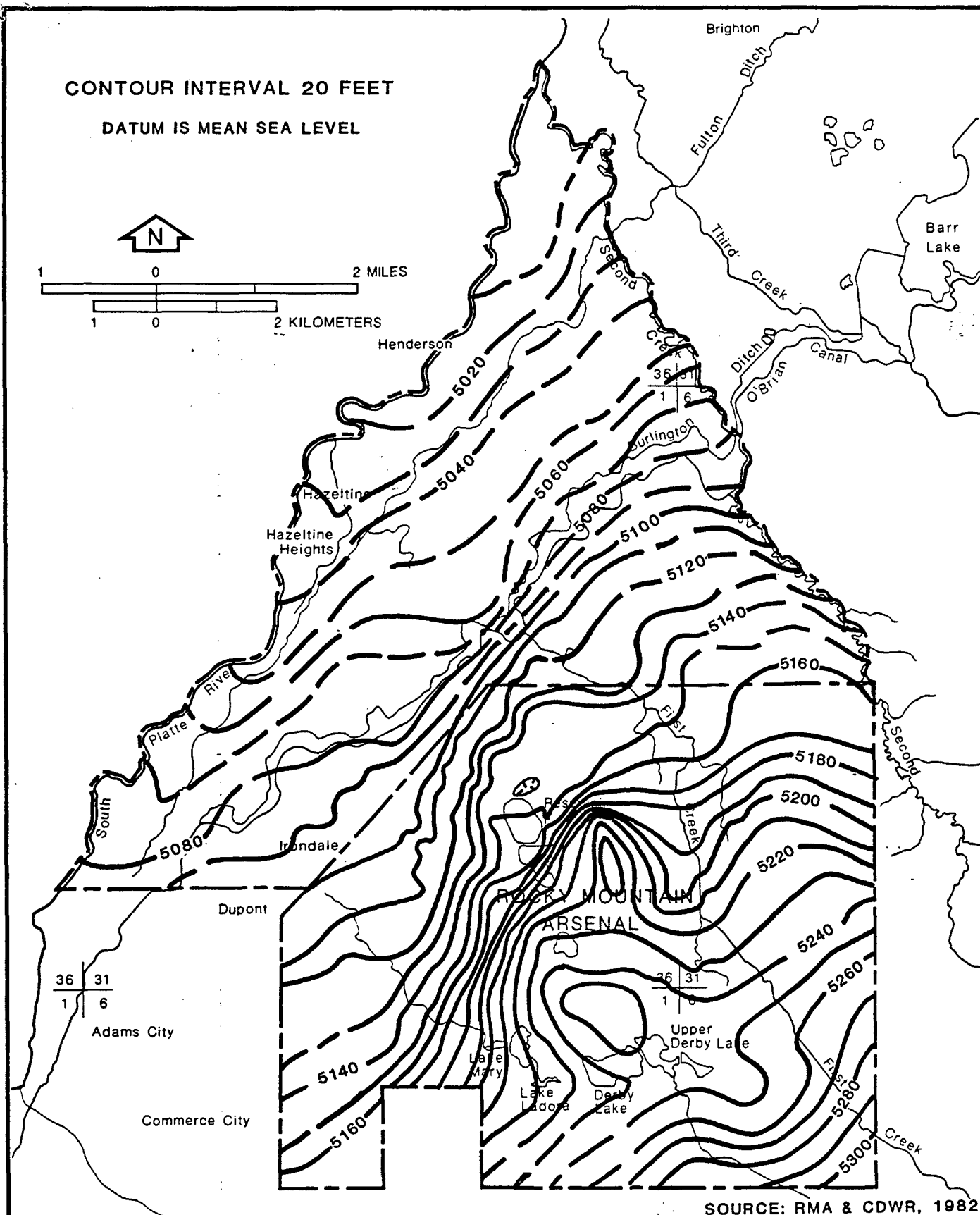


Figure 1.5-4  
WATER TABLE CONTOUR MAP  
OF STUDY AREA

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layers along the casing, thereby providing conduits for the migration of contamination between previously isolated alluvial and bedrock aquifers.

## 2.0 SAMPLE PLAN DESIGN

The objectives of the second phase of the consumptive use water well sampling program are to determine if any persons are consuming water with arsenal related compound concentrations above guidance levels and to augment data gathered in previous investigations to further delineate the nature and extent of potential contamination. As previously described, the ESE Phase I program consisted of collecting water samples from 117 alluvial and bedrock wells located offpost of RMA. Evaluation of the data generated from these samples indicated a zone of higher level contamination extending northwestward from the RMA boundary at 96th Avenue towards Hazeltine Heights and Henderson through Sections 3, 9, 10, and 14 of T2S, R67W (Figure 2.0-1). This contaminated area is characterized by the occurrence of detectable concentrations of DIMP, DBCP, DCPD, chlorinated pesticides, and aromatic and halogenated aliphatic solvents. At several locations in this study area, the concentrations (within the alluvial aquifer) of several of these organic compounds as well as chloride and fluoride exceed water quality guidance levels. Therefore, in order to further define the extent of contamination within this area, the intent of the second phase of consumptive use sampling was to only include alluvial wells located in this zone of higher contamination that had not previously been sampled.

The first step in designing the Phase II sampling plan was to review all existing Colorado State Engineer well completion records for the area of interest. The records available, although incomplete, indicated that nearly all permitted shallow wells in this area had either been previously sampled during Phase I or were determined to be unsuitable for sampling for numerous reasons (abandoned, poor well construction, location unidentifiable, access refused by land owner). However, it was apparent that many more wells did exist in the area which either had not been permitted or the permits and well completion records for them had been lost.

The second step, therefore, was to go to the Adams County Tax Assessor's Office in Brighton, Colorado and acquire property ownership maps of the

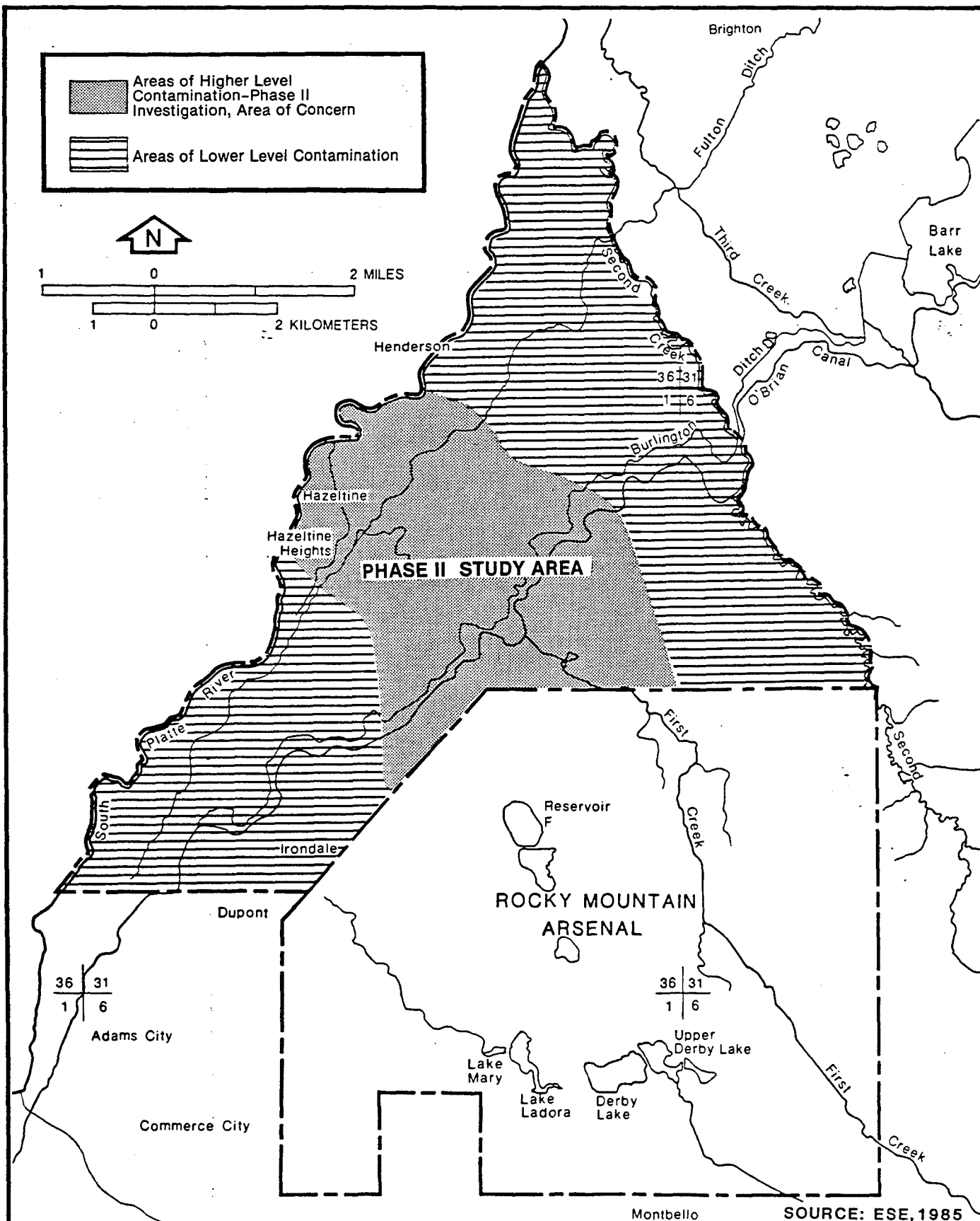


Figure 2.0-1  
CONTAMINATED AREAS OFFPOST OF RMA

Prepared for:  
**U.S. Army Program Manager's Office  
For Rocky Mountain Arsenal  
Aberdeen Proving Ground, Maryland**

Phase II study area. Property owner's names were obtained from the maps and cross-checked against current phone listings. The owner's names, addresses, and phone numbers were tabulated by section. Attempts were made to contact owners by phone to ascertain whether any wells existed on their property. When contacted, the owners were asked if any wells were located on their property, the number of wells, the depth of each well, the exact location of each well, whether the wells were permitted and in use, and the percent and type of use (domestic or irrigation).

A list of 69 candidate wells was compiled from owner responses. These candidate wells were divided into two categories based on reported use. Of the 69 wells, 17 were used for domestic purposes, and the remaining 52 were used for other purposes such as irrigation, livestock, or commercial supply.

The sampling plan limited total wells sampled to 40. The 69 wells were prioritized by reported use, location, proximity to wells sampled during Phase I, and quality of well construction information available. All alluvial wells were given the highest priority for sampling. The final candidate list of potential wells included 15 domestic wells ("DOM") and 31 other wells ("OTH") for a total of 46 wells. Two of the 17 domestic wells identified were dropped from the sampling program because those wells were completed into deep bedrock aquifers. Data from the Phase I Consumptive Use Program indicated that bedrock wells in the study area did not contain Arsenal related contaminants.

Twenty-one of the 52 irrigation, livestock, or commercial wells were dropped from the program because these wells were located adjacent to previously sampled wells, wells had been abandoned, and/or no well information was available.

An extra six wells were included in the event that higher priority wells were found unsuitable for sampling during field truthing activities.

Two of the 40 wells sampled during Phase II were also sampled during the Phase I investigation. These two wells were included in Phase II as a quality control check and to provide a comparison with Phase I data.

### 3.0 FIELD VERIFICATION AND SAMPLING

#### 3.1 CANDIDATE WELL VERIFICATION

Before actual sampling of the wells could begin, it was necessary to meet with the individual property owners and verify well information obtained earlier by phone. At each well site the following information (if available) was elicited from the owner or occupant:

- o Location of the well head on the property;
- o Depth of the well;
- o Owner's name and mailing address;
- o Present use of the well (i.e., domestic water supply, irrigation, livestock);
- o Pump type;
- o Casing type and screened interval;
- o Treatment, storage, or pressure systems to avoid;
- o Closest sampling point possible near well head; and
- o Ability to purge the well casing of the requisite five volumes and dispose of the evacuated water.

The data sheet used to record information obtained for each well is presented in Figure 3.1-1.

#### 3.2 UNSUITABLE WELLS

During the course of the field verification phase, 9 of the 46 candidate wells were found to be unsuitable for sampling for various reasons. The unsuitable wells and reasons for deletion from the sampling program are given in Table 3.2-1.

#### 3.3 ALTERNATIVE WELLS

The field verification program identified 37 wells of the 46 candidate wells as appropriate for sampling. However, as the sampling plan allowed for 40 wells to be sampled, three additional wells could be included in the program. All remaining wells from the original list of 69 in the area of interest proved to be inappropriate because of location, depth, or access. Therefore it was necessary to perform a field reconnaissance and interview property owners in order to locate three additional wells. Two abandoned wells and one currently operable irrigation well were



# **RMA OFFPOST FIELD DATA SHEET**

Well Number (ESE System) \_\_\_\_\_ Date \_\_\_\_\_  
 State Permit Number \_\_\_\_\_ 360° Prg Number \_\_\_\_\_  
 Permitted Use Code \_\_\_\_\_ Percent Use \_\_\_\_\_  
 Location: Address \_\_\_\_\_  
 Resident/Owner \_\_\_\_\_ Phone No. \_\_\_\_\_  
 Well Access \_\_\_\_\_  
 Producing Horizon: Alluvial \_\_\_\_\_ Bedrock \_\_\_\_\_ Formation Name \_\_\_\_\_  
 Date Installed \_\_\_\_\_ Pump Location/Type \_\_\_\_\_  
 Casing \_\_\_\_\_ Annular Space at Well Head \_\_\_\_\_  
 Treatment, storage or pressure systems to avoid \_\_\_\_\_  
 Closest/Best Sampling Point \_\_\_\_\_  
 Well Depth \_\_\_\_\_ Source \_\_\_\_\_  
 Screened Interval \_\_\_\_\_ Source \_\_\_\_\_  
 Static Water Level \_\_\_\_\_ Source \_\_\_\_\_  
 Five (5) Annular space/casing volumes = \_\_\_\_\_ Gallons  
 Ability to dispose of 5 casing volumes \_\_\_\_\_  
 Comments \_\_\_\_\_

## **SAMPLING**

Date \_\_\_\_\_ Time \_\_\_\_\_ ESE Sample No. \_\_\_\_\_ MRI No. \_\_\_\_\_  
 Fraction Sampled: C V V V V VB VB W1 W2 W3  
 Sampling Method \_\_\_\_\_  
 Visual Appearance of Sample \_\_\_\_\_ Depth to Water \_\_\_\_\_  
 Estimated Purge Volume \_\_\_\_\_ Rate \_\_\_\_\_ Drawdown \_\_\_\_\_  
 Temperature \_\_\_\_\_ pH \_\_\_\_\_ Calibration Standard pH 4 7 10  
 Specific Conductance \_\_\_\_\_ Calibration \_\_\_\_\_  
 Storage Conditions \_\_\_\_\_  
 Weather Conditions (including precipitation in previous 24 hrs) \_\_\_\_\_  
 Collected By \_\_\_\_\_  
 Comments \_\_\_\_\_

## **RIOTA**

Raise Livestock \_\_\_\_\_ Type \_\_\_\_\_  
 Raised as a Food Source \_\_\_\_\_ Private \_\_\_\_\_ Commercial \_\_\_\_\_  
 Source of Water \_\_\_\_\_  
 Source of Feed \_\_\_\_\_  
 Source of Water \_\_\_\_\_  
 Comments \_\_\_\_\_

SOURCE: ESE, 1985

Figure 3.1-1  
 RMA OFFPOST FIELD DATA SHEET  
 (PAGE 1 OF 2)

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 For Rocky Mountain Arsenal  
 Aberdeen Proving Ground, Maryland

**SKETCH OF SITE**

A large rectangular area for sketching the site. It contains horizontal lines for drawing and a north arrow pointing upwards.

Figure 3.1-1  
RMA OFFPOST FIELD DATA SHEET  
(PAGE 2 OF 2)

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Aberdeen Proving Ground, Maryland

Table 3.2-1. Wells Found to be Unsuitable for Sampling

Well Number	Owner	Location	Reasons for Deletion from Program
DOM-2	John S. Kemp 11610 Brighton Rd. Trustee for Polly Anna Mann (owner)	Fulton Ditch SW, SW, NE $\frac{1}{4}$ Sec. 3 T2S, R67W	Well abandoned, pump disconnected from power lines, no access for bailer or truck-mounted pump.
DOM-9	Joseph Monson P.O. Box 56 Greeley, CO 80637	104th Ave. & Havana NE, NW, NW $\frac{1}{4}$ Sec. 15 T2S, R67W	Well abandoned, pump disconnected from power lines, no access for bailer or truck-mounted pump.
DOM-13	John A. Yellinick 2 S. Dahlia St. Denver, CO 80222	E. 112th Ave. Ne, NW, NE $\frac{1}{4}$ Sec. 10 T2S, R67W	Deep well
OTH-6	Glen Murray 11010 Havana St. Brighton, CO 80601	11071 E. 112th Ave. SW, SE, SW $\frac{1}{4}$ Sec. 2 T2S, R67W	Debris in well; heavy oil slick on water's surface.
OTH-7	Elwood McDonald 11351 E. 112th Ave. Brighton, CO 80601	11351 E. 112th Ave. SW, SW, SE $\frac{1}{4}$ Sec. 2 T2S, R67W	Well struck by lightning, submersible pump inoperable, no access for bailer or truck-mounted pump.
OTH-21	Dave Heinze 10131 E. 96th Ave. Henderson, CO 80640	10131 E. 95th Ave. SW, SW, SE $\frac{1}{4}$ Sec. 5 T2S, R67W	Well abandoned, inaccessible
OTH-24	Sam & Morris Sigman 1360 S. Acoma St. Denver, CO 80223	Northwest of feed lot NW, NW, NE Sec. 22 T2S, R67W	Well abandoned, pump disconnected from power lines, no access for bailer or truck-mounted pump.
OTH-26	Glen Murray 11010 Havana St. Brighton, CO 80601	Northwest of OTH-15 SW, NW, NW $\frac{1}{4}$ Sec. 11 T2S, R67W	Well abandoned, pump disconnected from power lines, no access for bailer or truck-mounted pump.
OTH-31	Dave Heinze 10131 E. 96th Ave. Henderson, CO 80640	East of Burlington Ditch SW, SW, SE $\frac{1}{4}$ Sec. 15 T2S, R67W	Well abandoned, pump disconnected from power lines, no access for bailer or truck-mounted pump.

Source: ESE, 1985.

located and determined to be suitable for sampling. These wells were designated as OTH-6, OTH-7, and OTH-24, respectively, and incorporated into the sampling program. Table 3.3-1 lists the owners and locations of these alternative wells.

### 3.4 SAMPLING

Sampling began on September 30, 1985 and was completed October 11, 1985. Thirty-six of the 40 wells sampled were alluvial wells, while three wells, DOM-8, DOM-10, and DOM-14 were bedrock wells of uncertain depth and well DOM-15 is a well of multiple completion (alluvial and bedrock). The bedrock wells were sampled because the well owners were of the opinion that the wells were shallow enough to be in hydraulic contact with the alluvial aquifers. The completion interval for the bedrock wells were confirmed through owner communication and field and laboratory chemical characteristics indicative of local bedrock formations. A bedrock well characteristically will have a low specific conductivity (below 500  $\mu\text{mho/cm}$  at 25°C), high pH (above 8.0), low chloride concentrations, and high fluoride concentrations.

Two of the wells sampled during the investigation, OTH-5 and OTH-23, were also sampled during the Phase I investigation conducted in January 1985. These two wells were included in this phase as quality control checks and to provide a comparison with Phase I results. All other wells sampled during this investigation had not previously been sampled in Phase I.

Table 3.4-1 lists all wells sampled, sampling dates, and other pertinent information. A map of the area of interest with the locations of all wells sampled is presented in Plate 1.

Table 3.3-1. Alternative Wells

Well Number	Well Owner	Well Location	Previous Well Owner	Well Location
OTH-6	Emily Ferguson 11201 Brighton Rd. Henderon, CO 80640	In field northeast of owner's home SE, SE, SW $\frac{1}{4}$ Sec. 3 T2S, R67W	Glen Murray 11010 Havana St. Brighton, CO 80601	11071 E. 112th Ave. SW, SE, SW $\frac{1}{4}$ Sec. 2 T2S, R67W
OTH-7	Ida Mae Heckart 10850 Brighton Rd. Henderson, CO 80640	In field southeast of owner's home NW, NW, SW $\frac{1}{4}$ Sec. 10 T2S, R67W	Elwood McDonald 11351 E. 112th Ave. Brighton, Co 80601	11351 E. 112th Ave. SW, SW, SE $\frac{1}{4}$ Sec. 2 T2S, R67W
OTH-27	S.G. Company Address Unknown	In field west of Highway 85 SE, NW, NE $\frac{1}{4}$ Sec. 10 T2S, R67W	Sam & Morris Sigman 1360 Acoma St. Denver, CO 80223	Northwest of feed lot. NW, NW, NE $\frac{1}{4}$ Sec. 22 T2S, R67W

Source: ESE, 1985.

Table 3.4-1. Wells Sampled During the Phase II Consumptive Use Ground Water Sampling Program\*  
(Page 1 of 3)

Well Designation	ESE Sample Number	Location	Well Address	Owner's Address	Sample Date	Sample Time	Sample Method	Well Depth (ft)	Comments
DOM-1	559900	NE, SE, NE½ Section 3 T2S, R67W	11610 Brighton Rd. Henderson, CO 80640	Pollyanna Mann John Kemp: Trustee Same Address	10-02-85	1024	Grab	30	Shell Split Domestic Well
DOM-3	559902	SW, NE, SW½ Section 3 T2S, R67W	11481 Brighton Rd. Henderson, CO 80640	James Sweetman Same Address	10-03-85	1225	Grab	40	Domestic Well CDH Split
DOM-4	559903	SE, SE, SE½ Section 3 T2S, R67W	10495 E. 112th Ave. Brighton, CO 80601	Ronald & Vera Turner Same Address	9-30-85	1310	Grab	~35	Domestic Well
DOM-5	559904	SW, SE, SW½ Section 2 T2S, R67W	11071 E. 112th Ave. Brighton, CO 80601	Glen & Louise Murray 11010 Havana St. Brighton, CO 80601	10-01-85	0855	Grab	~40	Domestic Well Shell Split
DOM-6	559905	NW, NE, NE½ Section 11 T2S, R67W	11830 E. 112th Ave. Henderson CO 80640	Agricolae Same Address Tenant: Don Wright	10-01-85	1010	Grab	Unknown	Shell Split Domestic Well
DOM-7	559906	SE, SW, NE½ Section 10 T2S, R67W	Green Acres Turf Farm	So. Adams Partnership 3900 E. Mexico #750 Denver, CO 80210	10-03-85	1025	Grab	60-70	HRS, CDH Split, Domestic Well
DOM-8	559907	NE, NE, SE½ Section 9 T2S, R67W	10949 Brighton Rd. Henderson, CO 80640 Resident: J. Chrisbaum	Mobile Premix Concrete 1500 W. 12th Ave. Denver, CO 80204	10-10-85	0920	Grab	Unknown	Domestic Well Deep/Bedrock Arapahoe Fm.
DOM-10	559909	SE, SE, NE½ Section 15 T2S, R67W	10081 Havana St. Henderson, CO 80640 Tenant: Kenneson	Colorado Investor Realty 14991 E. Hampden, #380 Aurora, CO 80014	10-07-85	1030	Grab	Unknown Bedrock Well	CDH Split Domestic Well, Lower Denver Formation
DOM-11	559910	NW, NW, NW½ Section 14 T2S, R67W	E. 104th Ave. & Havana Henderson, CO 80640	Glen & Louise Murray 11010 Havana St. Brighton, CO 80601	10-01-85	1145	Grab	Unknown ~45	Shell, CDH Split Irrigation Well
DOM-12	559911	SW, SE, SW½ Section 15 T2S, R67W	9339 E. 96th Ave. Henderson, CO 80640	Hensel Phelps Construction P.O. Box 0 Greeley, CO 80640	10-04-85	0845	Grab	Unknown	Domestic Well, CDH Split
DOM-14	559913	SW, NE, NW½ Section 15 T2S, R67W	9520 E. 104th Ave. Henderson, CO 80640	Pioneer Steel & Tube Distributors Same Address	9-30-85	1056	Grab	~95	CDH Split Domestic Well, Lower Denver/Arapahoe Fms.
DOM-15	559914	NW, NW, NE½ Section 3 T2S, R67W	11923 Brighton Rd. Henderson, CO 80640	Brinkman-Woodward Construction Co. Same Address	10-09-85	0916	Grab	~32	Domestic Well, Alluvial/Arapahoe Fm.
OTH-1	559920	SE, SE, NW½ Section 3 T2S, R67W	11695 Brighton Rd. Henderson, CO 80640	Pete C. Zarlengo Same Address	10-10-85	1225	Grab	35	Irrigation Well
OTH-2	559921	NE, NE, SW½ Section 3 T2S, R67W	11591 Brighton Rd. Henderson, CO 80640	C.D. & Mabel Gentry Same Address	10-03-85	1140	Pumped	20	Lawn, Irrigation Well
OTH-3	559922	NW, NE, SW½ Section 3 T2S, R67W	11521 Brighton Rd. Henderson, CO 80640	Albert Frei Sand & Gravel Same Address	10-10-85	1130	Grab	12	Irrigation Well Used as Domestic Supply
OTH-4	559923	NW, NE, SE½ Section 3 T2S, R67W	Adjacent To Pumpkin Field; No Address	River Bend Assoc. Union Tower Bldg. 165 S. Union Blvd. Lakewood, CO 80228	10-09-85	1235	Pumped	54	Irrigation Well

Table 3.4-1. Wells Sampled During the Phase II Consumptive Use Ground Water Sampling Program  
(Continued, Page 2 of 3)

Well Designation	ESE Sample Number	Location	Well Address	Owner's Address	Sample Date	Sample Time	Sample Method	Well Depth (ft)	Comments
OTH-5	559924	SW, NE, SW $\frac{1}{2}$ Section 2 T2S, R67W	11420 Havana St. Brighton, CO 80601	Owen Bakes Same Address	10-03-85	0915	Grab	Unknown	HRS Split Lawn, Irrigation Well Sampled During Phase I Investigation Well #2-67-02-04
OTH-6	559925	SE, SE, SW $\frac{1}{2}$ Section 3 T2S, R67W	In Field Northeast of Owner's Home	Emily Ferguson 11201 Brighton Rd. Henderson, CO 80640	10-11-85	1330	Pumped	46	Unused Irrigation Well
OTH-7	559926	NW, NW, SW $\frac{1}{2}$ Section 10 T2S, R67W	Southeast of Owner's Home in Field; No Address	Ida Mae Heckart 10850 Brighton Rd. Henderson, CO 80640	10-11-85	1110	Pumped	21	Unused Irrigation Well
OTH-8	559927	NE, SW, SE $\frac{1}{2}$ Section 3 T2S, R67W	In Field; No Address	River Bend Assoc. Union Tower Bldg. 165 S. Union Blvd. Lakewood, CO 80228	10-09-85	1415	Pumped	49	Unused Irrigation Well
OTH-9	559928	SW, SW, SW $\frac{1}{2}$ Section 3 T2S, R67W	In Field Behind Owner's Home	Emily Ferguson 11201 Brighton Rd. Henderson, CO 80640	10-01-85	1448	Pumped	11.7	Shell Split I
OTH-10	559929	SW, SW, NW $\frac{1}{2}$ Section 10 T2S, R67W	Behind Owner's House	Ida Mae Heckart 10850 Brighton Rd. Henderson, CO 80640	10-04-85	0950	Pumped	11.85	Irrigation Well
OTH-11	559930	SW, NE, NW $\frac{1}{2}$ Section 10 T2S, R67W	Adjacent to Cabbage Field; No Address	Kiku Tanaka Contact: Don Tanabe 11011 Brighton Rd. Henderson, CO 80640	10-11-85	0910	Grab	30	Irrigation Well
OTH-12	559931	SW, SE, NW $\frac{1}{2}$ Section 10 T2S, R67W	In Field Southeast of Owner's Home	Gerald Meyers 11020 Brighton Rd. Henderson, CO 80640	10-07-85	1130	Grab	53	CDM Split Irrigation Well
OTH-13	559932	SW, SW, NE $\frac{1}{2}$ Section 10 T2S, R67W	Green Acres Turf Farm 108th Ave. & Havana	S. Adams Partnership 3900 E. Mexico #750 Denver, CO 80210	10-03-85	1300	Grab	55	Irrigation Well
OTH-14	559933	SE, SW, SE $\frac{1}{2}$ Section 10 T2S, R67W	9985 E. 104th Ave. Henderson, CO 80640	Vulcan Mineral Tech Same Address	10-02-85	1600	Pumped	38.8	Shell Split Irrigation Well
OTH-15	559934	SE, NE, NW $\frac{1}{2}$ Section 11 T2S, R67W	No Specific Address	Glen & Louise Murray 11010 Havana St. Brighton, CO 80601	10-01-85	1300	Pumped	45	Irrigation Well
OTH-16	559935 559950	SE, SW, SW $\frac{1}{2}$ Section 1 T2S, R67W	12381 E. 112th Ave. Henderson, CO 80640	Walter Cramer Same Address	10-07-85	0920	Grab	40	CDM Split Irrigation Well
OTH-17	559936	NW, NW, SW $\frac{1}{2}$ Section 12 T2S, R67W	In Feed Lot; No Specific Address	DMH Cattle Co. 104th Ave. & Hwy 2 Henderson, CO 80640	9-30-85	1205	Grab	~45	Shell Split Livestock Supply
OTH-18	559937	SE, NE, NW $\frac{1}{2}$ Section 15 T2S, R67W	North of I-76 on Pioneer Steel & Tube Property	Joseph Monson P.O. Box 56 Greeley, CO 80632	10-07-85	1245	Grab	~50	Irrigation Well
OTH-19	559938	NW, SE, NW $\frac{1}{2}$ Section 15 T2S, R67W	South of I-76 No Specific Address	Joseph & William Monson P.O. Box 56 Greeley, CO 80632	9-30-85	0930	Grab	Unknown ~50	Shell; CDM Split Irrigation Well
OTH-20	559939	NW, SE, NE $\frac{1}{2}$ Section 15 T2S, R67W	West of Burlington Ditch; No Address	Colorado Investor's Realty 14991 E. Hampden, #380 Aurora, CO 80014	10-07-85	1510	Pumped	47	Irrigation Well

Table 3.4-1. Wells Sampled During the Phase II Consumptive Use Ground Water Sampling Program  
(Continued, Page 3 of 3)

Well Designation	ESE Sample Number	Location	Well Address	Owner's Address	Sample Date	Sample Time	Sample Method	Well Depth (ft)	Comments
OTH-22	559941	NW, SE, SW $\frac{1}{2}$ Section 13 T2S, R67W	In Wheat Field; No Specific Address	Adams County Joint Venture 720 Kipling, Ste. 201 Lakewood, CO 80215	10-02-85	1420	Pumped	38.8	Shell Split Irrigation Well
OTH-23	559942	SW, SW, SW $\frac{1}{2}$ Section 13 T2S, R67W	In Field North of Owner's Home	Thomas Smaaldone 9610 Peoria St. Henderson, CO 80640	10-08-85	0910	Pumped	10.52	Unused Irrigation Well, 360° Well Sampled During Phase I Investigation Well #2-67-13-05
OTH-24	559943	SE, NW, NE $\frac{1}{2}$ Section 10 T2S, R67W	In Field West of Hwy. 85	S.G. Company Address Unknown	10-11-85	0810	Grab	Unknown	Turf Farm Irrigation Well
OTH-25	559944	NW, NW, NE $\frac{1}{2}$ Section 3 T2S, R67W	11923 Brighton Rd. Henderson, CO 80640	Brinkman-Woodward Construction Co. Same Address	10-09-85	1030	Pumped	26.6	Unused Irrigation Well
OTH-27	559946	SW, SW, SW $\frac{1}{2}$ Section 15 T2S, R67W	79131 E. 96th Ave. Henderson, CO 80640	20 Employees Industrial Land Venture 8551 Richard Rd. Commerce City, CO 80022	10-02-85	1230	Grab	Unknown	Shell Split Irrigation Well
OTH-28	559947	NE, NE, SE $\frac{1}{2}$ Section 9 T2S, R67W	10915 Brighton Rd. Henderson, CO 80640 Resident: Jim Chrisbaum	Mobile Premix Concrete 1500 W. 12th Ave. Denver, CO 80204	10-10-85	0955	Pumped	16	Unused Irrigation Well
OTH-29	559948	NW, SW, NW $\frac{1}{2}$ Section 10 T2S, R67W	10961 Brighton Rd. Henderson, CO 80640	David & Mary Jordan Same Address	10-04-85	1335	Grab	~50	Irrigation Well
OTH-30	559949	NE, NE, NE $\frac{1}{2}$ Section 11 T2S, R67W	Turf Farm Well Southwest of Home Tenant: Glen Wright	Agricolae 11830 E. 112th Ave. Henderson, CO 80640	10-08-85	1010	Grab	Unknown	Irrigation Well

ft = feet

Source: ESE, 1985

\* All wells are completed into the alluvium unless otherwise indicated.



## 4.0 FIELD PROCEDURES

### 4.1 SAMPLING CRITERIA

After contacting property owners to schedule a date and time for sampling, a field crew was sent to the selected wells to collect samples. Upon arrival, well owners were briefly questioned to ensure that the appropriate well was available for sampling. The sampling team also inquired as to the precise location of the well head, the presence of any treatment systems, and the present uses of water from the sampled well.

Most samples were obtained using the owner's existing pump and distribution system. Samples collected in this manner are designated as grab samples. The wells were commonly purged and sampled from outdoor taps, although taps on indoor wash basins were sometimes used. Some of the systems included pressure tanks, with no existing provisions for sampling before the system entered the tank. Samples were not collected from supply lines leading from water softeners or water heaters. Wells containing pumps were not measured for depth to water or total well depth.

Where appropriate well completion records were available or the exact depth of the well was known, efforts were made to purge the well and distribution system of five times the volume of water contained in the well casing, screen and saturated annulus. Although most alluvial wells were readily purged of the requisite five volumes, evacuation of the larger 36 to 48 inch (in) diameter shallow wells and the two bedrock wells would have required excessive purging times. These wells were purged until pH and conductance measurements, taken five minutes apart, had stabilized. Time required for stabilization ranged from 45 minutes to over 2 hours. In the case of alluvial wells where well completion records were unavailable, the wells were purged until pH and conductance had stabilized, usually requiring 30 minutes to one hour after purging started. Records of the sampling point, flow rate and volume purged were maintained at all sampling sites.

Fourteen of the wells sampled either did not have pumps in place or the pump present was not in working condition. These wells were purged using a truck-mounted submersible pump. Before pumping, the total depth of the well and depth to water were measured using a weighted tape. The saturated casing and screen volumes were then calculated to determine the required purge volume. In most cases the diameter of these wells was so large as to preclude evacuation of five well volumes, but in each case the well was pumped until field parameters had stabilized and at least one well volume had been removed.

#### 4.2 FIELD MEASUREMENTS AND SAMPLE COLLECTION

Field measurements obtained onsite included pH, conductivity, and temperature. Measurement of pH was performed using a Beckman Model 021 pH meter equipped with a liquid-filled combination electrode and automatic temperature compensation probe. The pH meter was calibrated before use at each well site with pH 7.00 and pH 10.01 buffer solutions. For each well, a minimum of three pH measurements were made. Measurements were taken immediately after standardization, midway through the required purging time, and prior to sample collection. Where available information did not allow for calculation of the required purge volume, pH measurements were made at approximately five minute intervals. Precision of the reported pH values was estimated to be within +0.05 pH unit.

Conductance was measured using a YSI Model 32FL conductivity meter equipped with a temperature compensation probe. The conductivity meter was calibrated prior to initiation of the field program using 147 and 10,000 micromhos per centimeter ( $\mu\text{mho}/\text{cm}$ ) standards at 25 degrees celsius ( $^{\circ}\text{C}$ ). In addition, meter circuitry was checked using a YSI Model 3166 Calibration set. Meter calibration was verified periodically throughout the study, and was not found to deviate significantly. Conductivity was measured concurrently with pH at each well site. Both conductivity at the sample temperature and specific conductance at  $25^{\circ}\text{C}$  were recorded after each measurement. Precision of the reported specific conductance was estimated to be on the order of +1 percent of scale.

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Sample temperature was measured using the temperature compensation probes furnished with the pH and conductivity meters. Large differences between ambient temperature and sample temperature sometimes hindered accurate measurement of ground water temperatures. Although agreement between the conductivity and pH meter was often within several tenths of a degree, discrepancies of as much as a degree were sometimes observed. Precision of the reported temperature is therefore estimated to be on the order of  $\pm 1^{\circ}\text{C}$ .

After purging five saturated casing volumes or stabilization of pH and conductance, samples for laboratory analysis were collected. Prepared sample bottles were obtained from the ESE laboratory under proper chain-of-custody. Where possible the required suite of bottles was filled directly from the owner's tap with a minimum of aeration. Pumped samples were obtained directly from the discharge line. The field sampling team wore clean polyvinyl chloride (PVC) surgical gloves while filling sample bottles. Lids or septa were discarded when contaminated through contact with fingers or soil. All volatile samples were checked to verify the absence of air bubbles. Degradation rates were minimized by storing the samples in ice chests at temperatures near  $4^{\circ}\text{C}$ . No chemical preservatives were added to any of the sample fractions.

#### 4.3 SAMPLE SHIPMENT

As required by protocol, sample fractions were packaged and either shipped or hand delivered to the ESE laboratories at the end of each field day. After the field team had returned to the office, samples designated for shipment to the ESE laboratory in Gainesville, Florida were encased in bubble wrap, placed in coolers, and iced. Proper chain-of-custody documents were completed by the field team leader and placed in each cooler. Coolers were then sealed with evidence tape and initialed before shipping via an overnight delivery service. Samples slated for analysis at the ESE laboratory in Englewood were hand delivered to the laboratory coordinator per chain-of-custody requirements.

#### 4.4 SAMPLE SPLITS

Sample splits were collected by four organizations: Cenref Laboratories (contracted by Shell Chemical Company); Colorado Department of Health; Camp, Dresser & McKee (CDM-contracted by EPA); and HRS Water Consultants [(HRS) Contracted by South Adams County Water and Sanitation District (SACWSD)]. Each split was collected in containers supplied by each individual organization under the supervision of a representative from that organization. However, CDH splits were collected by ESE personnel in the field and then picked-up by a CDH representative at the ESE office. A total of 21 split sets were collected at 18 well locations. Table 4.4-1 presents a listing of samples split with Cenref, CDH, CDM, and HRS respectively.

Table 4.4-1. RMA Phase II Consumptive Use Sampling Sample Splits

Well Number	Laboratories Receiving Splits
DOM-1	ESE, Cenref
DOM-3	ESE, CDH
DOM-5	ESE, Cenref
DOM-6	ESE, Cenref
DOM-7	ESE, CDH, HRS
DOM-10	ESE, CDM
DOM-11	ESE, Cenref, CDH
DOM-12	ESE, CDH
DOM-14	ESE, CDH
OTH-5	ESE, HRS
OTH-9	ESE, Cenref
OTH-12	ESE, CDM
OTH-14	ESE, Cenref
OTH-16	ESE, CDM
OTH-17	ESE, Cenref
OTH-19	ESE, Cenref, CDM
OTH-22	ESE, Cenref
OTH-27	ESE, Cenref

Source: ESE, 1985.

## 5.0 LABORATORY ANALYSIS

Analysis of samples was conducted jointly by ESE laboratories in Gainesville, Florida and Englewood, Colorado. Both laboratories have undergone a series of rigorous USATHAMA certification procedures designed to ensure accurate and precise determination of the analytes of interest and have implemented USATHAMA Quality Assurance (QA) procedures to continuously monitor the quality of analytical data. A detailed discussion of analyst certification and quality assurance criteria is presented in Appendix A of the RMA Offpost Contamination Assessment Technical Plan (ESE, 1984).

Each suite of samples was quantitatively analyzed for 15 total contaminants. Analytes not detected during the Phase I investigation were not analyzed during Phase II. The parameters which were not analyzed during Phase II include DMMP, PCPMS, PCPMSO, PCPMSO<sub>2</sub>, 1,4-dithiane, 1,4-oxathiane, toluene, benzene, and xylenes. A summary of Phase II analytes, their respective analytical methods, and hold times is presented in Table 5.0-1.

Detection limits for many of the organic compounds have been changed since completion of the Phase I Consumptive Use Program. These changes reflect a transition from semi-quantitative to quantitative analyte determinations in accordance with USATHAMA certification procedures. A comparison of detection limits for the analytical methods utilized during the Phase I and Phase II Consumptive Use investigations is provided in Table 5.0-2.

Table 5.0-1. Chemical Analysis - Offpost Study Area

Analysis/Analytes	Hold Time	Level of Certification	Reference Methods	Method
<b><u>Organochlorine Pesticides</u></b>				
Aldrin Endrin Dieldrin Isodrin	Extract as quickly as possible. (No more than 7 days). Analyze within 30 days of extraction.	Quantitative	EPA 608	CAP-GC/ECD
<b><u>Volatile Organohalogens</u></b>				
Chlorobenzene Chloroform Carbon Tetrachloride Trans-1,2-Dichloroethylene Trichloroethylene (TCE) Tetrachloroethylene	14 days 14 days 14 days 14 days 14 days 14 days	Quantitative	EPA 601	PACK-GC/Hall
<b><u>DCPD</u></b>				
Dicyclopentadiene	Extract as quickly as possible. (No more than 7 days). Analyze extract within 30 days of extraction.	Quantitative	EPA 608	CAP-GC/FID
<b><u>DIMP</u></b>				
Diisopropylmethylphosphonate	Extract as quickly as possible. (No more than 7 days). Analyze within 30 of extraction.	Qualitative	EPA 622	PACK-GC/FPD-P
<b><u>DBCP</u></b>				
Dibromochloropropane	14 days	Quantitative		CAP-GC/ECD
<b><u>Chloride/Fluoride</u></b>				
Chloride Fluoride	28 days 28 days	Quantitative	EPA 300	Ion Chromatograph

Source: ESE, 1985.

Table 5.0-2. Revised Detection Limits--  
Phase II Consumptive Use Sampling

Compound	Quantitative Detection Limit (Phase II)	Semi-Quantitative Detection Limit (Phase I)
DIMP	10.0 µg/l	1.9 µg/l
DBCP	0.13 µg/l	0.113 µg/l
DCPD	9.31 µg/l	24.0 µg/l
Aldrin	0.07 µg/l	0.13 µg/l
Dieldrin	0.06 µg/l	0.16 µg/l
Endrin	0.05 µg/l	0.07 µg/l
Isodrin	0.06 µg/l	0.18 µg/l
Chloroform	1.4 µg/l	1.4 µg/l
Trichloroethylene	1.1 µg/l	1.1 µg/l
Tetrachloroethylene	1.3 µg/l	1.3 µg/l
Trans-1,2-Dichloroethylene	1.2 µg/l	1.2 µg/l
Carbon Tetrachloride	2.4 µg/l	2.4 µg/l
Chlorobenzene	0.58 µg/l	0.58 µg/l
Chloride	4.8 mg/l	0.9 mg/l
Fluoride	1.2 mg/l	1.2 mg/l

Source: ESE, 1986.



## 6.0 ANALYTICAL RESULTS

The analytical results have been tabulated and are presented in Appendix A. The corresponding sampling locations are shown on Plate 1. The data have been subjected to a rigorous QA evaluation, and have been transferred into the USATHAMA Level 2 data base.

Data have been tabulated by well number and arranged according to actual sampling date. The sampled wells were divided into two categories based on well usage. Wells designated with the prefix of OTH- are used for irrigation or livestock while those wells designated with the prefix of DOM- are domestic use wells. Domestic use wells include all water supplies which are used for drinking and/or sanitation purposes at private residences or commercial establishments. Well DOM-11 was converted from a domestic supply well to an irrigation well. Well OTH-3 is used for sanitation purposes and was therefore considered a domestic well.

Concentrations of organic analytes are reported in units of micrograms per liter ( $\mu\text{g}/\text{l}$ ), which is approximately equivalent to parts-per-billion (ppb). Results that are reported as "less than" (<) a particular value indicate that the analyte was undetected. Following the field sampling data, blank sample data are tabulated.

## 7.0 DISCUSSION

### 7.1 WATER QUALITY CRITERIA

Most of the potential contaminants identified at RMA are of concern with regard to human health considerations. A summary of available toxicological information for the contaminants of interest is provided in Table 7.1-1. The guidance levels summarized in Table 7.1-1 represent maximum recommended contaminant levels based on ingestion of drinking water as an exposure pathway.

Where federally approved water quality criteria or standards exist, those values have been adopted as guidance levels for use in this report. However, guidance levels for aldrin and dieldrin have been revised to reflect the limitations of state-of-the-art analytical technology. Water quality criteria for these two chlorinated pesticides are several orders of magnitude lower than technically attainable analytical detection limits. Therefore, no analytical means exist with which to evaluate water quality with respect to the criteria for those pesticides. The guidance levels for aldrin and dieldrin that are adopted in this report reflect concentrations which can be detected analytically with a high degree of confidence.

Water quality criteria have not been developed for many of the compounds associated with RMA activities. For those compounds where no approved standards exist, approximate guidelines developed by the U.S. Army Office of the Surgeon General (OTSG) or the U.S. Army Medical and Bioengineering Research and Development Laboratory (USAMBRDL) have been adopted as guidance levels for use in this report.

### 7.2 DATA PRESENTATION

A review of analytical data indicates the presence of organic and inorganic contaminants in ground water samples collected from wells located northwest of RMA. A summary of compounds detected, frequency detected, and frequency exceeding water quality guidance levels is presented in Table 7.2-1. Because some wells contain more than one contaminant, simply summing the frequencies detected or frequencies

Table 7.1-1. Water Chemistry Parameter Guidance Levels and Supporting Information

Parameter	Water Quality Criteria	Criteria Reference	Guidance Level	Guidance Level Reference	Detection Limit
Aldrin	0.00074 µg/l <sup>(1)</sup>	Human Health Criteria for 10 <sup>-5</sup> risk level from "Final Water Quality Criteria" 45 CFR 79318, 28 November 1980.	0.2 µg/l <sup>(2)</sup>	Guidance from OTSG (Army) until standards are developed.	0.07 µg/l
Endrin	0.2 µg/l	EPA National Interim Primary Water Standards	0.2 µg/l <sup>(3)</sup>	—	0.05 µg/l
Dieldrin	0.00071 µg/l <sup>(1)</sup>	Human Health Criteria for 10 <sup>-5</sup> risk level from "Final Water Quality Criteria" 45 CFR 79318, 28 November 1980.	0.2 µg/l <sup>(2)</sup>	Guidance from OTSG (Army) until standards are developed.	0.06 µg/l
Isodrin	—	No approved criteria exists.	0.2 µg/l <sup>(2)</sup>	Guidance from OTSG (Army) until standards are developed.	0.06 µg/l
Dicyclopentadiene (DCPD)	—	No approved criteria exists.	24 µg/l <sup>(2)</sup>	Request by state of Colorado to meet standard of three times the odor threshold of 8 µg/l.	9.31 µg/l
Dibromochloropropane (DBCP)	—	No approved criteria exists.	0.2 µg/l <sup>(2)</sup>	State of Colorado Department of Health Limit per letter to Commander, RMA; 26 January 1979.	0.13 µg/l
Diisopropylmethylphosphonate (DIMP)	—	No approved criteria exists.	500 µg/l <sup>(2)</sup>	Criteria developed and recommended by USAMBRDL. Concurred by National Academy of Sciences Committee on Military Environmental Research (February, 1977).	10 µg/l
Chlorobenzene	488 µg/l	Human Health Criteria for 10 <sup>-5</sup> risk level from "Final Water Quality Criteria" 45 CFR 79318, 28 November 1980.	488 µg/l <sup>(2)</sup>	—	0.58 µg/l
Chloroform	1.9 µg/l	Human Health Criteria for 10 <sup>-5</sup> risk level from "Final Water Quality Criteria" 45 CFR 79318, 28 November 1980.	1.9 µg/l <sup>(2)</sup>	—	1.4 µg/l
Carbon Tetrachloride	5 µg/l	Human Health Criteria for 10 <sup>-5</sup> risk level from "Final Water Quality Criteria" 45 CFR 79318, 28 November 1980.	5 µg/l	—	2.4 µg/l
trans-1,2-Dichloroethylene	70 µg/l	No approved criteria exists.	70 µg/l	Guidance from OTSG (Army) until standards are developed.	1.2 µg/l
Trichloroethylene	5 µg/l	Human Health Criteria for 10 <sup>-5</sup> risk level from "Final Water Quality Criteria" 45 CFR 79318, 28 November 1980.	5 µg/l	—	1.1 µg/l
Tetrachloroethylene	8 µg/l	Human Health Criteria for 10 <sup>-5</sup> risk level from "Final Water Quality Criteria" 45 CFR 79318, 28 November 1980.	8 µg/l <sup>(2)</sup>	—	1.3 µg/l
Chloride	250 mg/l	EPA National Interim Secondary Drinking Water Regulation.	250 mg/l <sup>(3)</sup>	—	4.8 mg/l
Fluoride	2.4 mg/l	State of Colorado Department of Health limit per letter Commander RMA; 2 August 1971.	2.4 mg/l <sup>(2)</sup>	—	1.2 mg/l

- (1) Criteria not based on achievable detection limits.  
 (2) Suggested Limit.  
 (3) Mandatory Limit.  
 (4) Qualitative Analysis.

Table 7.2-1. Water Quality Summary of Analytical Results--Number of Positive Results Among 40 Well Samples Analyzed.

Compounds Detected	Frequency Detected (1)	Frequency Exceeding Water Quality Guidance Levels (2)
Diisopropylmethylphosphonate (DIMP)	16	1
Aldrin	1	0
Endrin	1	1
Dieldrin	2	1
Isodrin	0	0
Dibromochloropropane (DBCP)	0	0
Dicyclopentadiene (DCPD)	1	1
Chloroform	0	0
t-1,2-Dichloroethylene	0	0
Trichloroethylene	0	0
Tetrachloroethylene	1	1
Chloride	36(3)	3
Fluoride	27(3)	2

(1) Frequency with which identified compounds occurred in concentrations at or above the analytical detection limits presented in Table 5.0-2.

(2) Frequency with which identified compounds occurred in concentrations at or above the water quality guidance levels presented in Table 7.1-1.

(3) Naturally occurring constituents.

Note: Remaining compounds determined did not occur in concentrations at or above the analytical detection limits presented in Table 5.0-2.

exceeding guidance levels would result in an erroneously high number of contaminated wells.

Organic contaminants were detected in samples collected from 18 wells which draw water from the alluvial aquifer. Of these 18 wells, two contained one or more organic contaminants at concentrations exceeding the water quality guidance levels presented in Table 7.1-1. No organic contaminants were detected in bedrock wells. A summary of water quality results by well usage is presented in Table 7.2-2.

Of the 12 domestic water supply wells sampled during the Phase II Program, no wells contained organic contaminants exceeding water quality guidance levels. Both of the wells which exceed water quality guidance levels for organic contaminants are completed in the alluvial aquifer. One of these wells, reportedly used for agricultural irrigation (DOM-11), exceeds the guidance level for DIMP and chloride. A second well, OTH-23, exceeds guidance levels for DCPD, dieldrin, endrin, tetrachloroethylene, chloride, and fluoride. Well OTH-23 is an abandoned irrigation well located near the RMA north boundary. This well was sampled during the Phase I Program and at that time water quality guidance levels were exceeded for several organic contaminants. Four bedrock wells were sampled, DOM-8, DOM-10, DOM-14, and DOM-15. None of these wells contained organic contaminants above analytical detection limits.

Background concentrations of chloride and fluoride in uncontaminated wells are dependent on the aquifer sampled. Konikow (1977) determined a historical background chloride concentration of 40 mg/l in 1940 from an alluvial aquifer modeling study for an area adjacent to RMA. However, because of extensive irrigation and use of road salt, present chloride concentrations may locally be much higher. On the basis of the Phase I study, a background fluoride concentration of 2.0 mg/l is considered representative of the alluvial aquifer.

Representative chemical analyses of water from bedrock wells in the Denver Basin have been tabulated by CDWR (1976) and have been used to determine background conditions for the Denver and Arapahoe Formations.

Table 7.2-2. Water Quality Summary of Analytical Results by Well Usage--Organic Contaminants

Well Usage	Number of Wells Sampled	Frequency Detected <sup>1</sup>	Detected Below Water Quality Guidance Levels <sup>2</sup>	Detected At or Above Water Quality Guidance Levels <sup>3</sup>
Domestic	12	3	3	0
Livestock/ Irrigation	<u>28</u>	<u>15</u>	<u>13</u>	<u>2</u>
TOTAL	40	18	16	2

1 Frequency with which identified compounds occurred in concentrations at or above the analytical detection limits presented in Table 5.0-2.

2 Frequency with which identified compounds occurred in concentrations below the water quality guidance levels presented in Table 7.1-1.

3 Frequency with which identified compounds occurred in concentrations at or above the water quality guidance levels presented in Table 7.1-1.

Denver Formation chloride and fluoride concentrations are below 120 mg/l and 2.5 mg/l, respectively, in thirteen reported analyses from the Denver Basin study. Arapahoe Formation chloride and fluoride concentrations are below 65 mg/l and 4.5 mg/l, respectively, in 42 reported analyses from the Denver Basin study.

Although elevated concentrations of chloride and fluoride are associated with RMA activities, these inorganic anions are natural constituents of uncontaminated ground water. Three alluvial wells have chloride concentrations exceeding water quality guidance levels. Two of these wells, DOM-11 and OTH-23, also contain detectable concentrations of DIMP. The third well, OTH-12, contains only chloride at concentrations above guidance levels. Well OTH-12 is used for agricultural irrigation. Only one alluvial well sampled during the Phase II Program contained fluoride at concentrations above guidance levels. This well, OTH-23, also contained elevated concentrations of several organic contaminants. Well OTH-23 is an agricultural irrigation well which is presently abandoned and is located near the RMA north boundary.

Four of the wells sampled during the Phase II Program, DOM-8, DOM-10, DOM-14, and DOM-15 draw water from bedrock aquifers. Information supplied by the well owners suggests that wells DOM-10 and DOM-14 may be completed in the lower Denver Formation. Wells DOM-8 and DOM-15 may be completed in the Arapahoe Formation. Samples from these wells exhibit geochemical characteristics consistent with bedrock ground water, including high pH, low to intermediate conductivity, low chloride and intermediate to high fluoride concentrations. DOM-8 contains fluoride in excess of the water quality guidance level (3.98 mg/l). This fluoride concentration is above the background level of 2.5 mg/l. However, a lack of elevated fluoride concentration in the adjacent alluvial aquifer indicates that the elevated fluoride level in well DOM-8 is naturally occurring. This well contains none of the other associated organic contaminants or elevated chloride concentrations characteristic of alluvial contamination. Data from the Phase I Consumptive Use Study indicates chloride concentrations in bedrock samples are at or below detection limits. Elevated fluoride concentrations in samples from

bedrock wells are considered a natural characteristic of confined ground water in this region (CDWR, 1976), and are not considered indicative of contamination. Elevated fluoride concentrations were noted in all bedrock wells sampled during the Phase I study.

A number of figures have been prepared in order to display the distribution of contaminants in the alluvial aquifer. Figure 7.2-1 displays the locations of alluvial wells containing contaminant concentrations in excess of water quality guidance levels. Data plots of contaminant distribution in the alluvial aquifer are presented in Figures 7.2-2 through 7.2-7 for DIMP, DCPD, chlorinated pesticides, aromatic and halogenated aliphatic solvents, chloride, and fluoride, respectively. A plot of fluoride concentrations in the bedrock wells sampled is provided in Figure 7.2-8. Most of the figures use several symbols which indicate analytical concentrations below the detection limit, concentrations greater than detection limit but less than water quality guidance levels, and concentrations greater than water quality guidance levels.

Areal trends in alluvial ground water contamination at concentrations in excess of detection limits are similar to those determined during the Phase I Program. A linear zone of contamination extends northwestward from the intersection of First Creek and the RMA northern boundary towards Hazeltine Heights and Henderson, through Sections 3, 9, 10, 11, and 14 of T2S, R67W. Contaminants in concentrations exceeding guidance levels include DIMP, DBCP, dieldrin, endrin, tetrachloroethylene, chloride, and fluoride.

### 7.3 PHYSICAL/CHEMICAL CONTAMINANT PROPERTIES

The physical/chemical properties of contaminants detected offpost is related directly to their mobility and persistence in ground water. The information presented represents a relatively limited review of readily available information, including several reports conducted under the auspices of USATHAMA (Cogley and Foy, 1978; Kolakowski, 1979; Callahan, et al., 1979; Spangord, et al., 1979; and Rosenblatt, et al., 1975). U.S. EPA reports were also consulted. Most of the parameter values are estimates based on theoretical methods such as those presented



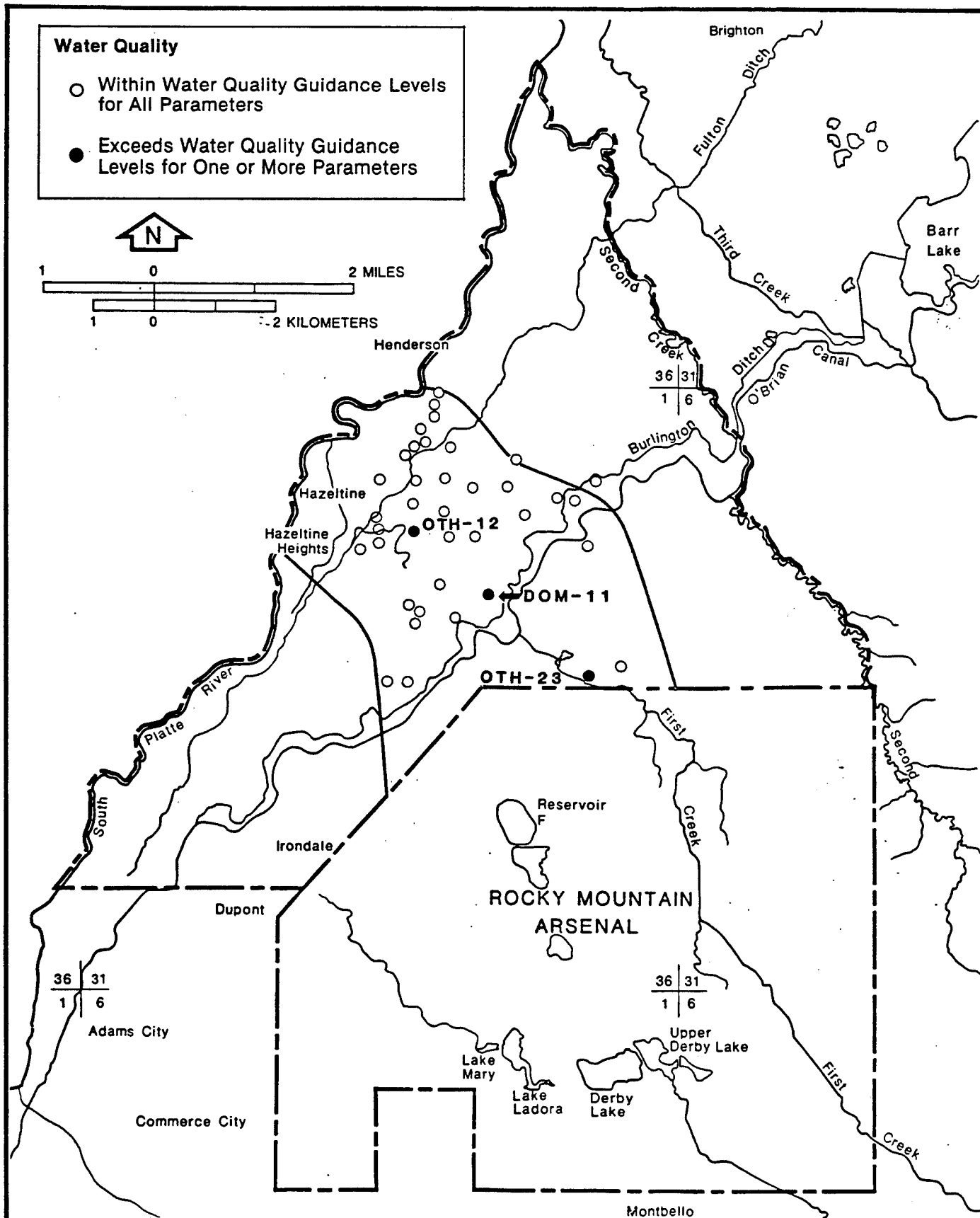


Figure 7.2-1  
WATER QUALITY IN ALLUVIAL WELLS  
RMA CONSUMPTIVE USE PHASE II PROGRAM  
SEPTEMBER-OCTOBER 1985

SOURCE: ESE, 1986

Prepared for:  
**U.S. Army Program Manager's Office  
For Rocky Mountain Arsenal**  
Aberdeen Proving Ground, Maryland

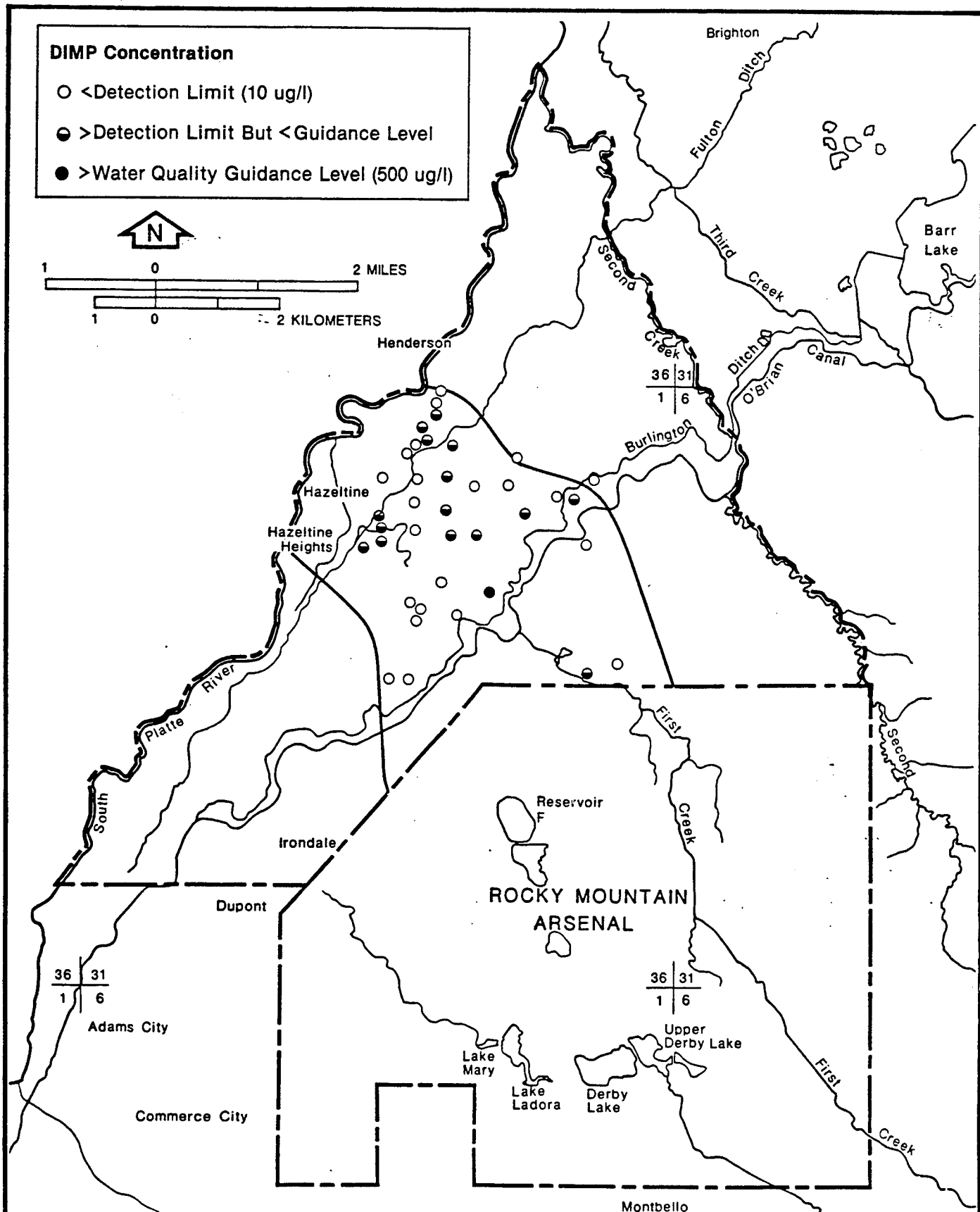


Figure 7.2-2  
DIMP ASSESSMENT IN ALLUVIAL WELLS  
RMA CONSUMPTIVE USE PHASE II PROGRAM  
SEPTEMBER-OCTOBER 1985  
SOURCE: ESE, 1986

Prepared for:  
**U.S. Army Program Manager's Office  
For Rocky Mountain Arsenal**  
Aberdeen Proving Ground, Maryland

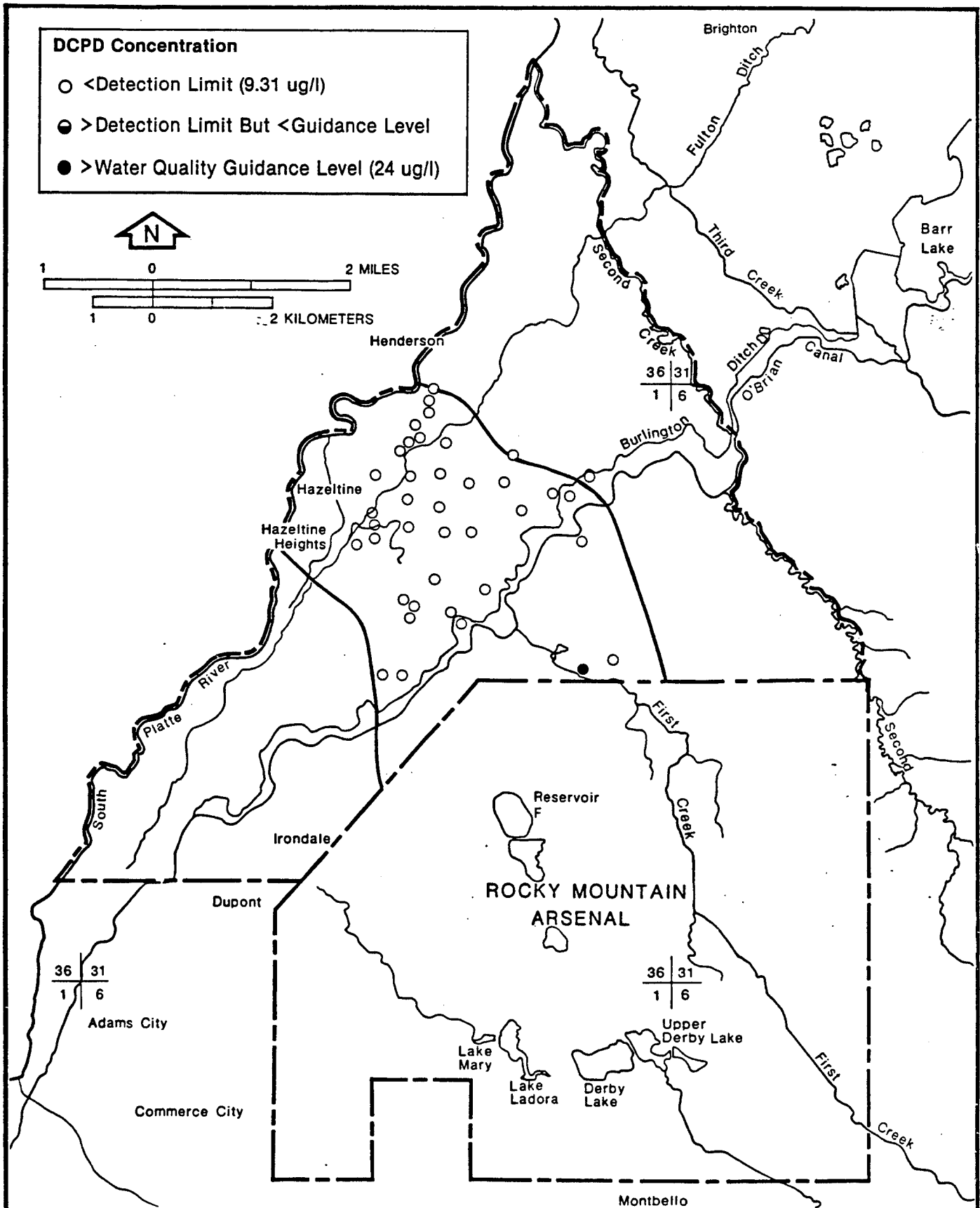


Figure 7.2-3  
DCPD ASSESSMENT IN ALLUVIAL WELLS  
RMA CONSUMPTIVE USE PHASE II PROGRAM  
SEPTEMBER-OCTOBER 1985  
SOURCE: ESE, 1986

Prepared for:  
U.S. Army Program Manager's Office  
For Rocky Mountain Arsenal  
Aberdeen Proving Ground, Maryland

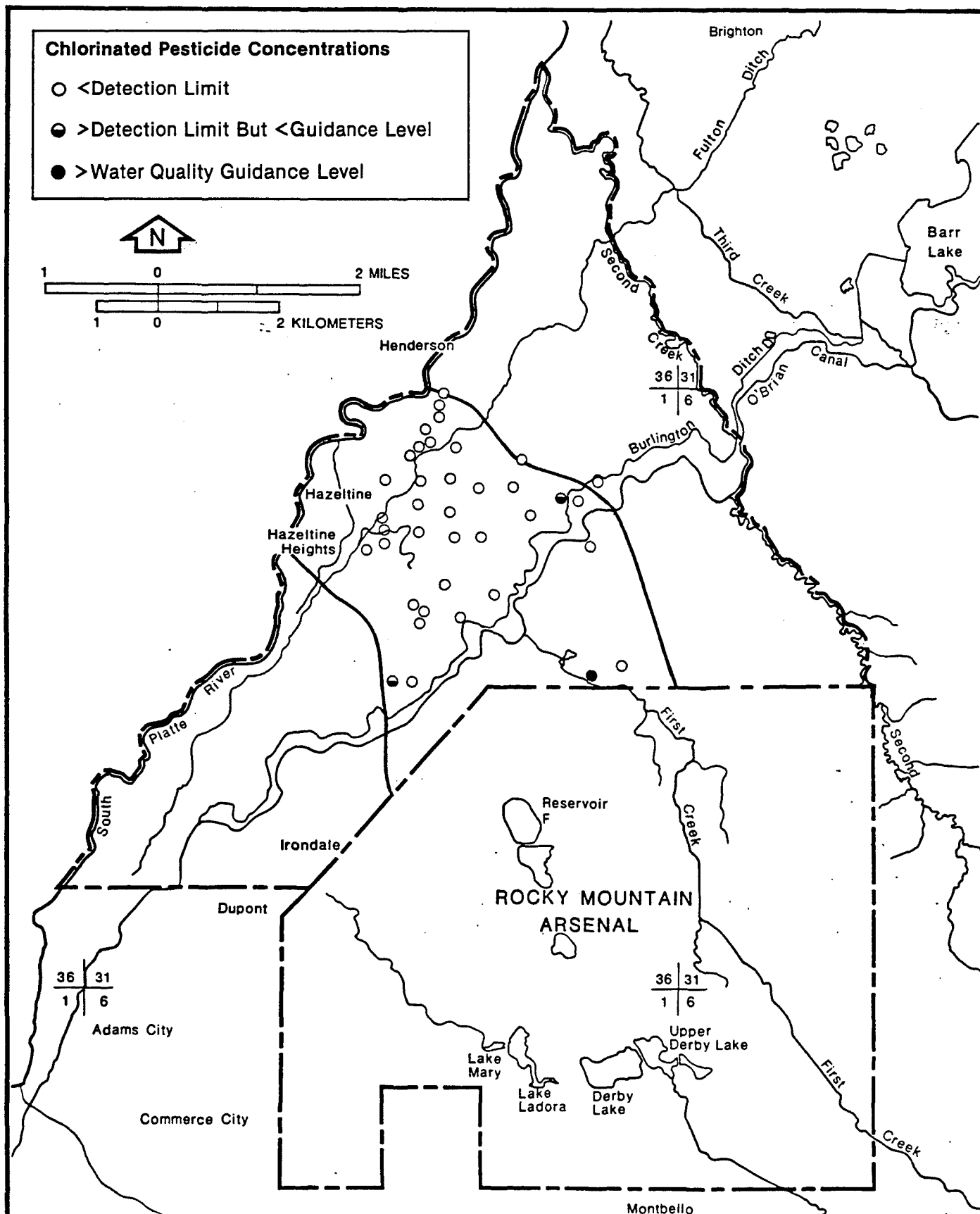


Figure 7.2-4  
 CHLORINATED PESTICIDE ASSESSMENT IN  
 ALLUVIAL WELLS  
 RMA CONSUMPTIVE USE PHASE II PROGRAM  
 SEPTEMBER-OCTOBER 1985  
 SOURCE: ESE, 1986

Prepared for:  
**U.S. Army Program Manager's Office**  
**For Rocky Mountain Arsenal**  
 Aberdeen Proving Ground, Maryland

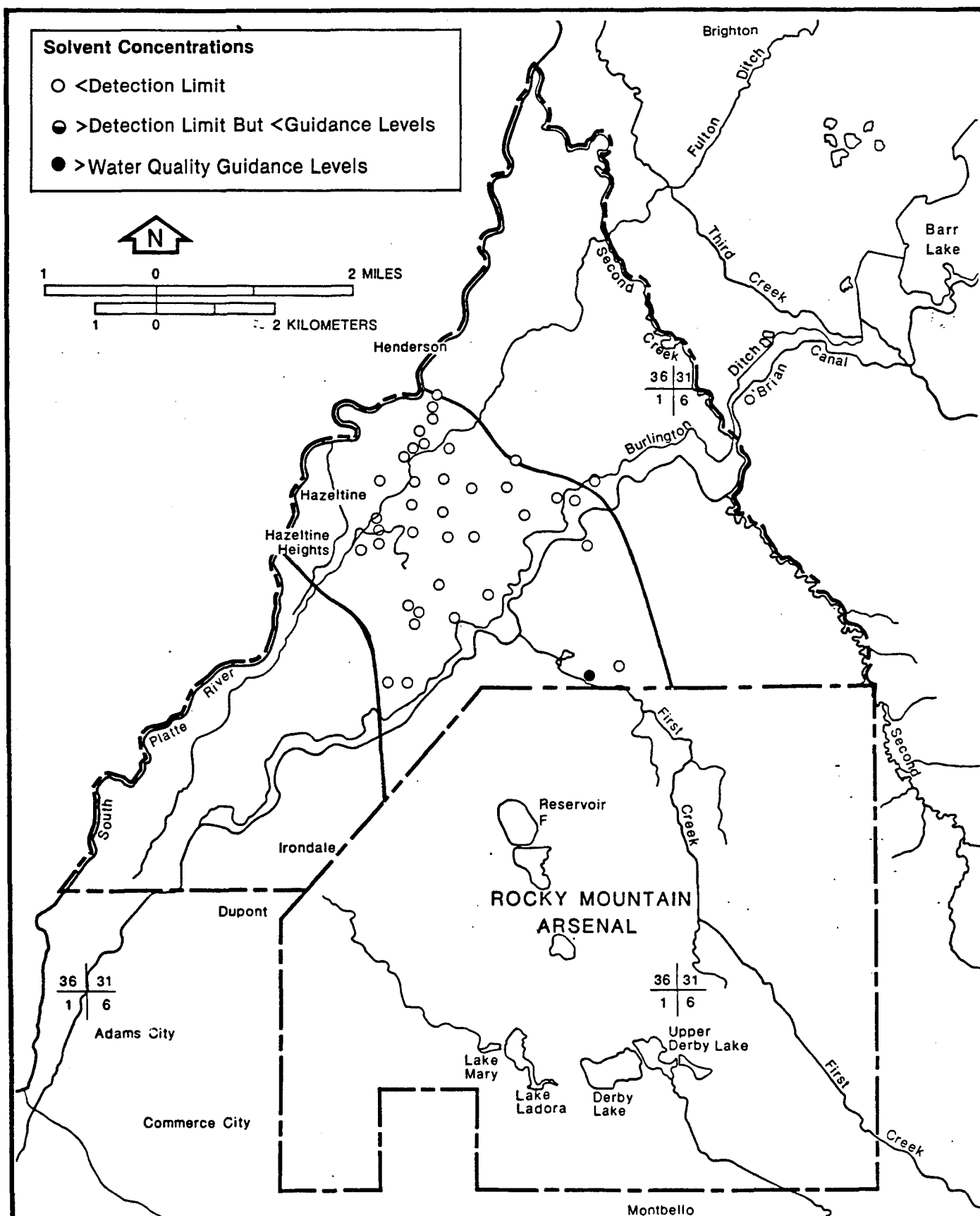


Figure 7.2-5  
AROMATIC AND HALOGENATED ALIPHATIC SOL-  
VENT ASSESSMENT IN ALLUVIAL WELLS  
RMA CONSUMPTIVE USE PHASE II PROGRAM  
SEPTEMBER-OCTOBER 1986  
SOURCE: ESE, 1986

Prepared for:  
**U.S. Army Program Manager's Office  
For Rocky Mountain Arsenal**  
Aberdeen Proving Ground, Maryland

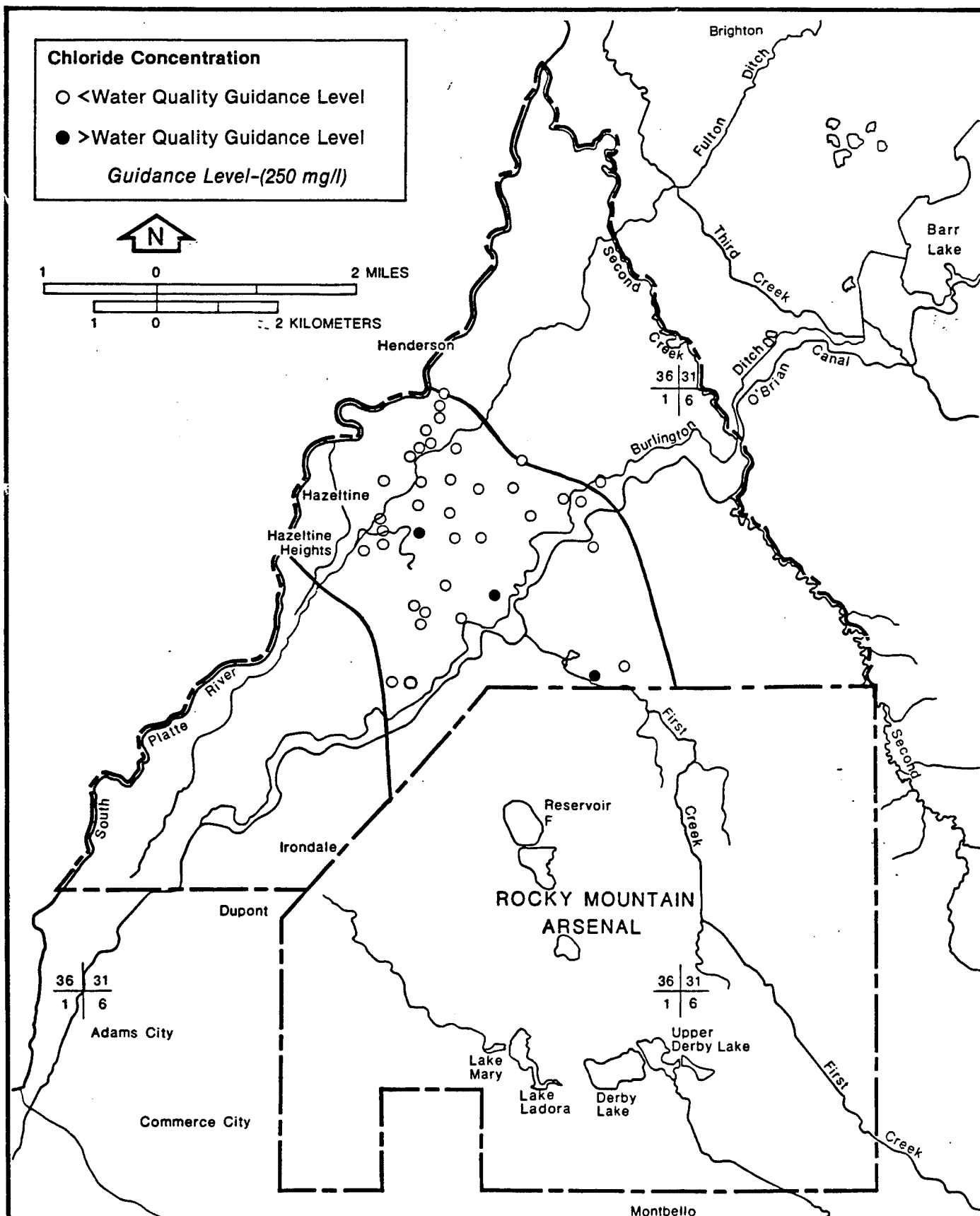


Figure 7.2-6  
CHLORIDE ASSESSMENT IN ALLUVIAL WELLS  
RMA CONSUMPTIVE USE PHASE II PROGRAM  
SEPTEMBER-OCTOBER 1985

SOURCE: ESE, 1986

Prepared for:  
**U.S. Army Program Manager's Office  
For Rocky Mountain Arsenal**  
Aberdeen Proving Ground, Maryland

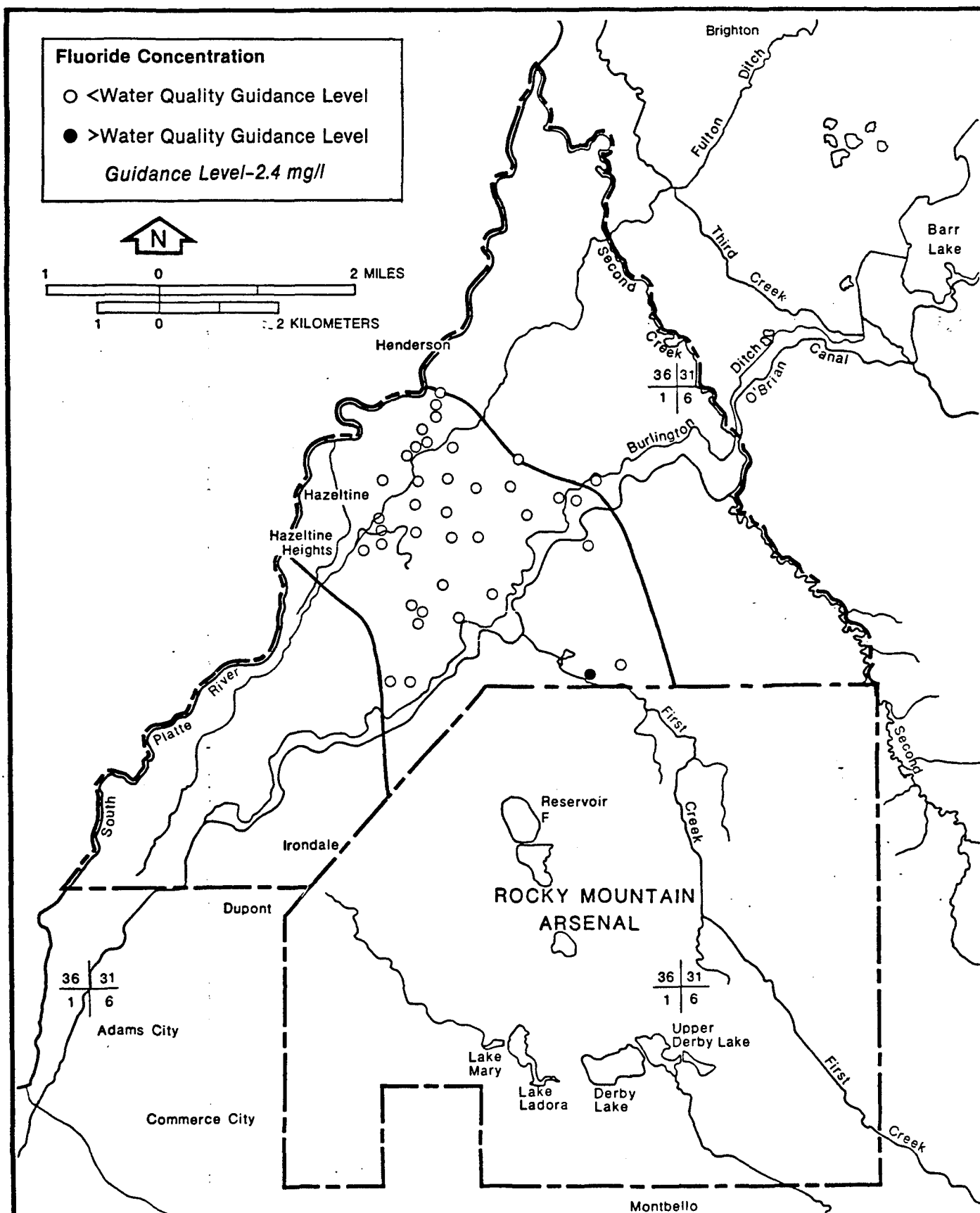


Figure 7.2-7  
 FLUORIDE ASSESSMENT IN ALLUVIAL WELLS  
 RMA CONSUMPTIVE USE PHASE II PROGRAM  
 SEPTEMBER-OCTOBER 1985  
 SOURCE: ESE, 1986

Prepared for:  
**U.S. Army Program Manager's Office**  
**For Rocky Mountain Arsenal**  
 Aberdeen Proving Ground, Maryland

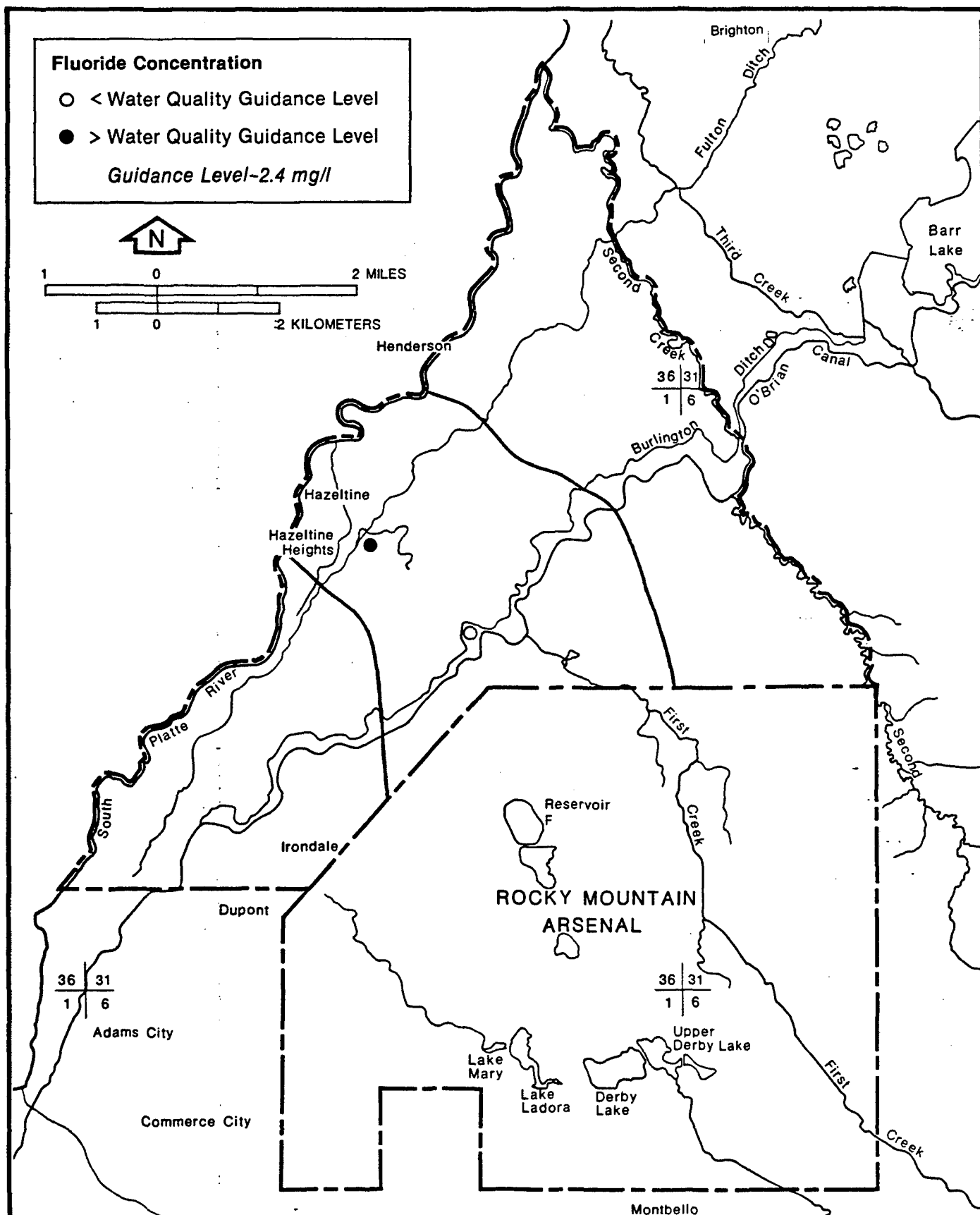


Figure 7.2-8  
 FLUORIDE ASSESSMENT IN BEDROCK WELLS  
 RMA CONSUMPTIVE USE PHASE II PROGRAM  
 SEPTEMBER-OCTOBER 1985  
 SOURCE: ESE, 1986

Prepared for:  
 U.S. Army Program Manager's Office  
 For Rocky Mountain Arsenal  
 Aberdeen Proving Ground, Maryland



by Lyman, et al. (1982). Given the substantial uncertainty inherent in such estimates, as well as the unverified use of secondary sources, the precise numerical values are relatively uncertain. Furthermore, specific numerical values will not be used in any calculations in this document, so it is appropriate to characterize chemical properties as falling within broad ranges of values. In the following discussions of physical/chemical properties, the relevance of each property to contaminant migration behavior at RMA and the offpost study area will be briefly summarized and contaminants will be categorized according to their properties.

Contaminant solubility (S) in water is an important property affecting its potential for migration by surface or ground water. Solubility of each compound in water is dependent, in general, on the temperature of the water. To provide comparability, the solubility of all compounds has been tabulated for the range of 20 to 25°C which is slightly higher than the annual average temperature of ground water in the study area. Solubility of inorganic species will depend strongly on the presence of other dissolved species. Polar organic contaminant solubility will also depend on ionic strength. All the organic contaminants found at RMA are non-polar or moderately polar so this factor is expected to be insignificant. The solubility of pertinent contaminants is summarized in Table 7.3-1. Many of the solubility values have been estimated via correlation with the octanol-water partition coefficient,  $K_{ow}$ , which in turn was estimated from chemical structure by methods summarized by Lyman, et al. (1982).

The organic carbon partition coefficient ( $K_{oc}$ ) describes the tendency for organic contaminants to adsorb or associate with natural organic materials. Natural organic matter is found in relatively high concentration in soils and sediments, and in relatively lower concentrations in aquifer materials.  $K_{oc}$  is not relevant to the mobility of most inorganics, with the possible exception of heavy metals, and is negligible for inorganic contaminants found at RMA. Contaminants with high  $K_{oc}$  values are almost completely immobilized in fertile, shallow soils and organic-rich sediments characteristic of productive surface

Table 7.3-1. Physical/Chemical Properties of RMA Migrating Contaminants

	Solubility (S)	Organic Partition Coefficient (Koc)	Henry's Law Constant (H)	Vapor Pressure (P)
DIMP	Very High	Low	Moderate	Moderate
DCPD	Moderate	Low	Very High	High
Aldrin	Very Low	Very High	Low	Very Low
Endrin	Very Low	Very High	Very Low	Very Low
Dieldrin	Very Low	Very High	Very Low	Very Low
Tetrachloroethylene	High	Moderate	Very High	Moderate
Fluoride	High	Very Low	Very Low	Very Low
Chloride	High	Very Low	Very Low	Very Low

Key:

	S (ppm)	Koc	H <sub>ATM</sub> m <sup>3</sup> /M	P (mmHg)
Very High	> 1300	>100,000	>9x10 <sup>-3</sup>	>50
High	110-1300	10,000-1,000,000	7x10 <sup>-4</sup> -9x10 <sup>-3</sup>	0.5-50
Moderate	10-110	1,000-10,000	4x10 <sup>-5</sup> -7x10 <sup>-4</sup>	1x10 <sup>-2</sup> -0.5
Low	1-10	100-1,000	3x10 <sup>-6</sup> -4x10 <sup>-5</sup>	2x10 <sup>-4</sup> -1x10 <sup>-2</sup>
Very Low	< 1	< 100	<3x10 <sup>-6</sup>	2x10 <sup>-4</sup>

Source: ESE, 1984.

water bodies. Aquifer materials, including the alluvial aquifer at RMA, typically exhibit much lower concentrations of organic carbon, and  $K_{oc}$  is a relatively less important parameter in most aquifers. The  $K_{oc}$  values of pertinent contaminants are categorized in Table 7.3-1. All of the  $K_{oc}$  values have been estimated from the octanol-water partition coefficient, which in turn was estimated from chemical structure by methods summarized by Lyman, et al. (1982).

The Henry's Law constant (H) characterizes partitioning of chemicals between air and water. Contaminants with a high Henry's Law constant will tend to volatilize, or evaporate, from water into air. The Henry's Law constant is a dominant property influencing the residence time of chemicals in surface waters, where volatilization frequently controls contaminant behavior. Volatile organic compounds, such as tetrachloroethylene are likely to disappear from flowing streams within minutes to hours (Callahan, et al., 1979).

Volatilization, and the associated Henry's Law constant, is relatively less important in most ground water systems. Volatilization will be most important in ground water systems having the following characteristics:

1. Non-artesian conditions;
2. Shallow water table;
3. Low soil moisture in the overlying unsaturated zone;
4. Rapid flow rates; and
5. Moderately to highly porous overburden.

Characteristics 1, 2, 3, and 5 are associated with conditions that enhance gas exchange (high porosity, absence of a confining aquitard or aquiclude, absence of pore-filling water, and limited thickness of overburden). Characteristic 4 follows from the fact that dispersion in a ground water body is proportional to linear velocity. Since most of these conditions are characteristic of the alluvial system in the RMA offpost study area, volatilization may be a significant process for the removal of contaminants from ground water in the alluvial system, particularly where the water table is less than 3 m below the surface.

The Henry's Law constants of pertinent contaminants are categorized in Table 7.3-1. The Henry's Law constant has been estimated by dividing the vapor pressure (P) by the solubility, although this method is often inaccurate for relatively insoluble compounds, such as the chlorinated pesticides.

The vapor pressures of pertinent contaminants are categorized in Table 7.3-1. Most of the vapor pressures are based on measured values and have been corrected to temperatures of approximately 20 to 25°C.

#### 7.4 CONTAMINATION DISTRIBUTION AND MIGRATION

Contaminant distributions and concentration gradients in the alluvial aquifer derived from the Phase I Consumptive Use Study results indicate that contaminants may be preferentially transported along zones of higher permeability associated with paleochannels in the bedrock surface. These sinuous bedrock valleys have been filled with sands and gravels which are coarser and more transmissive than the overlying alluvium. Elevated contaminant concentrations extend northwestward from the RMA northern boundary along a paleochannel associated with the First Creek drainage. This channel appears to bifurcate, transporting contaminants northwest towards Hazeltine Heights and north towards an area south of Henderson. Another minor channel appears to transport contaminants northward from the north boundary, east of a bedrock high in the northwest quarter of Section 13, and through Sections 11, 12, and 13. A contour map of the bedrock surface is presented in Figure 1.5-3, and a simplified map showing the inferred locations of these paleochannels is presented in Figure 7.4-1.

Results of the Phase II Consumptive Use sampling effort support the conclusions derived from the Phase I data. The increased density of alluvial wells in the Phase II Program allows a zone of DIMP and chloride contamination to be traced northward through an area where data were previously sparse. Comparison with the bedrock surface map indicates an excellent correlation between detectable DIMP concentrations and a paleochannel associated with the First Creek drainage. This paleochannel

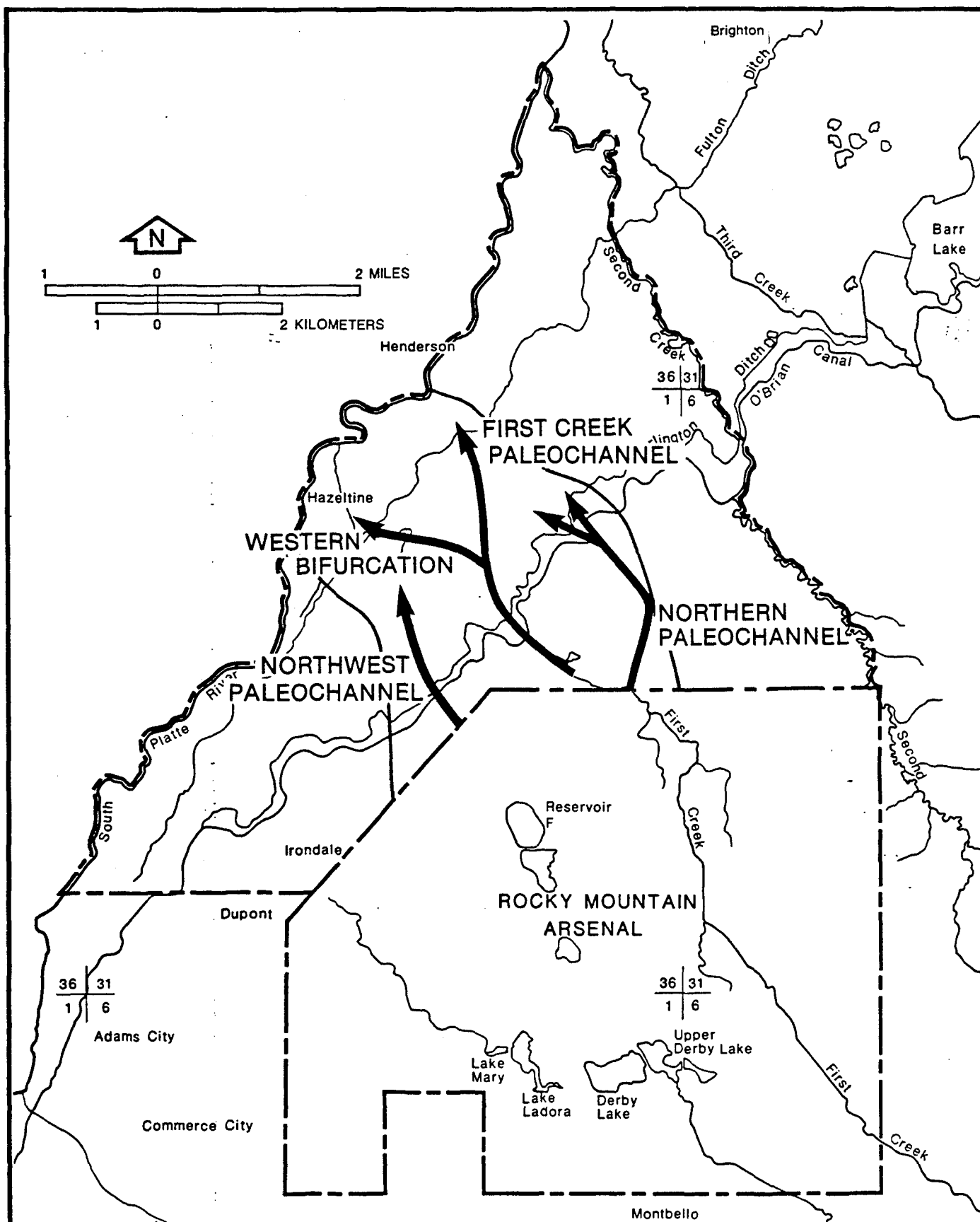


Figure 7.4-1  
INFERRED FLOW PATHS AND LOCATIONS  
OF BEDROCK SURFACE PALEOCHANNELS

Prepared for:  
U.S. Army Program Manager's Office  
For Rocky Mountain Arsenal  
Aberdeen Proving Ground, Maryland

07/11/86

can be traced from the RMA north boundary along First Creek northward towards Henderson.

The relationship of the main First Creek paleochannel to contamination in the Hazeltine Heights area is less clear. Contaminants may be transported along a westward bifurcation in the First Creek paleochannel, or may be derived from a paleochannel leading northward from the RMA northwest boundary. Samples collected from alluvial wells located south of Hazeltine Heights and completed in the northwest boundary paleochannel indicate the absence of detectable concentrations of DIMP. The absence of organic contaminants in this northwest boundary paleochannel suggests that DIMP contamination near Hazeltine Heights is related to the First Creek paleochannel. An isolated occurrence of elevated chloride concentration is observed in well DOM-12, which is completed in the northwest boundary paleochannel. Three Army M-series wells which are located near the northwest boundary and completed in this paleochannel have been selected for incorporation into the Revision III-360° Monitoring Program (ESE, 1986). Results from sampling of these M-Series wells may clarify any correlation between elevated chloride concentration at well DOM-12, the occurrence of DIMP near Hazeltine Heights, and the potential for contaminant migration along the RMA northwest boundary.

A third potential migration pathway is defined by a paleochannel situated east of a bedrock high and running north from the RMA north boundary. Phase I results indicated the presence of DIMP, DBCP, dieldrin, endrin, and chlorinated solvents in samples from alluvial wells completed along this northern paleochannel. Phase II results indicate the presence of DIMP in well OTH-30 and aldrin in well DOM-6. These wells are completed along a bifurcation of this northern channel, extending the zone of contamination along this northern paleochannel to a distance of approximately two miles from the RMA northern boundary. These organic contaminants are absent from a sample collected from well OTH-22, which is situated between the northern paleochannel and the adjacent bedrock high near the RMA northern boundary. However, the sample from OTH-22 does exhibit a relatively high chloride concentration. The O'Brian Canal and Burlington Ditch may also be pathways for the DIMP measured in OTH-30

and aldrin in DOM-6. Endrin, aldrin, and dieldrin were commonly used as agricultural pesticides. Therefore their presence in these paleochannels may not be an indicator of Arsenal contamination.

Generally speaking, the mobility of offpost contaminants may be described on the basis of their physical/chemical properties. Those compounds characterized by high solubilities and low organic carbon partition coefficients remain in the aqueous phase and exhibit high mobilities in an unconfined ground water environment. Those compounds that exhibit low solubilities and high organic carbon partition coefficients are strongly adsorbed to carbonaceous aquifer materials and exhibit low mobilities in an unconfined ground water environment. Compounds with high Henry's Law constants exhibit a tendency to be volatilized from the aqueous to the gaseous phase, although this effect is most pronounced in surface water systems.

The contaminants detected in offpost ground water have been grouped into three mobility classes based on their physical/chemical characteristics. The first class consists of persistent and highly mobile compounds and includes the inorganics and DIMP. These compounds have a high potential for widespread migration offpost, if released in significant quantities onpost. The second class is the volatile organic compounds highly mobile but with some tendency to be lost from ground water through volatilization. This class includes DCPD and tetrachloroethylene. The third class includes the extremely immobile pesticides aldrin, endrin, and dieldrin.

Theoretical contaminant mobilities are clearly reflected in the contaminant distribution near the northern boundary along the First Creek paleochannel. The theoretically most mobile contaminants, including chloride and DIMP, have migrated from the northern boundary to the South Platte River in relatively high concentrations. The theoretically least mobile compounds, the chlorinated pesticides, are restricted in distribution along the First Creek paleochannel to the area immediately northwest of the northern boundary. This contaminant distribution indicates that compounds such as the chlorinated pesticides may be

retarded in their relative rates of migration. These chlorinated pesticides all exhibit high octanol/water coefficients and are strongly adsorbed by naturally occurring organic carbon compounds. The retarded rate of migration suggests that sufficient quantities of organic carbon may occur within the First Creek paleochannel to serve as adsorption sites for these compounds.

Along the northern paleochannel, however, low concentrations of DIMP and chlorinated pesticides were detected at a distance of approximately two miles from the RMA northern boundary. The transport of relatively immobile chlorinated pesticides over this distance indicates a low capacity for attenuation for these compounds, and suggests a paucity of naturally occurring organic carbon in this northern paleochannel system.

In naturally occurring sediments, organic carbon is generally associated with the fine sand and silt grain size fractions. Available stratigraphic information from the offpost Contamination Assessment monitoring wells indicates an apparent thickening of coarse grained alluvial sediments within paleochannels in the bedrock surface. It has been postulated that this relative coarsening of alluvial sediments results in enhanced permeabilities along the paleochannels, and provides pathways for enhanced ground water flow and contaminant migration. The coarsening of these paleochannel fill sediments may also lead to decreased organic carbon content and a concurrent decrease in sediment sorptive capacity for organic contaminants. In this manner, contaminant transport is enhanced through both increased ground water permeability and decreased sorptive capacity in the coarse alluvial sediments filling erosional paleochannels in the bedrock surface. The reason for dissimilarities in adjacent channels is uncertain at present, but may be a reflection of further heterogeneity in the alluvial aquifer.

Alluvial stratigraphy is currently under further investigation. Available borehole logs from various investigations of the offpost area are being compiled and evaluated. Sediment samples collected during drilling of the Offpost Contamination Assessment monitoring wells have been submitted for analysis of grain size distribution and organic carbon



content. Assimilation of this additional hydrogeologic and geochemical data may provide further insight regarding the effects of aquifer heterogeneity on contaminant migration patterns.

The restricted occurrence of pesticides near the RMA northern boundary along the First Creek paleochannel may also indicate that the pesticides are diluted below detectable levels beyond this area, possibly by infiltration associated with O'Brian Canal and Burlington Ditch. However, the relatively small decrease in both DIMP and chloride concentrations northwest of these canals suggests that potential dilution of contaminants due to dispersion or to surface water infiltration is relatively insignificant.

#### 7.5 COMPARISON OF PHASE I AND PHASE II CONSUMPTIVE USE SAMPLING RESULTS

The comparison between Phase I and Phase II sampling results is limited by several incongruities between the two programs. These differences include:

- o Wells Sampled-The area identified by the Phase I Program as a "higher level contamination" area was the sole focus of Phase II sampling. Therefore, the two sample sets do not overlap, with the exception of two wells, OTH-5 and OTH-23.
- o Revised Analytical Procedures-Some laboratory procedures were changed from semi-quantitative to quantitative methods. This resulted in revised detection limits as listed in Table 5.0-2.
- o Hydrologic Conditions-Several factors, such as time of the year and recent precipitation events affect the ground water flow and quality in an alluvial aquifer. These hydrologic factors vary from one season to the next, but may be responsible for important differences, such as relative dilution, in samples collected over different sampling periods.

With these limitations, only generalized comparisons can be made.

Table 7.5-1 is the comparison between the results of Phase I and Phase II sampling for the two wells sampled in both programs. This comparison is representative of the conclusions that may be drawn from comparing data from the two wells sampled in both phases.

Table 7.5-1. Comparison of Phase I and Phase II Consumptive Use  
Sampling Program Data for Wells OTH-5 and OTH-23  
(All concentrations in µg/l)

Analysis	Well No. OTH-5		Well No. OTH-23	
	Phase I (1-11-85)	Phase II (10-3-85)	Phase I (12-18-84)	Phase II (10-8-85)
DCPD	<24.0	<9.31	48*	25.2*
DBCP	<0.2	<0.13	<0.2	<0.13
DIMP	8.3	<10.0	4,700*	210
Aldrin	<0.1	<0.07	<0.1	<0.07
Endrin	<0.07	<0.05	<0.07	0.8
Dieldrin	<0.2	<0.06	NA	0.9
Isodrin	<0.2	<0.06	<0.2	<0.06
Chlorobenzene	<0.6	<0.58	<0.6	<0.58
Chloroform	<1.0	<1.4	<1.0	<1.4
Carbon Tetrachloride	<2.0	<2.4	<2.0	<2.4
Dichloroethylene	<1.0	<1.2	<1.0	<1.2
Trichloroethylene	<1.0	<1.1	<1.0	<1.1
Tetrachloroethylene	<1.0	<1.3	9	10
Chloride	81,500	54,100	374,000*	308,000*
Fluoride	1,700	<1,200	2,890*	2,520*

\* Indicates values above water quality guidance levels.

NA Not Analyzed.

The most consistent factor in Table 7.5-1 is that the values above analytical detection limits in Phase I remain above the detection limits in Phase II, although the exact numerical value varies. The areas of high level contamination from Phase I are generally reconfirmed by Phase II. It may be concluded that with the limitations discussed, these qualitative comparisons are much more applicable for the two data sets than the quantitative comparisons.

#### 7.6 SAMPLE SPLITS

Comparison of analytical results from sample splits provided to concerned MOA parties indicates excellent correspondence between laboratories. Sample splits were prepared in the field and provided to Shell, CDH, EPA, and SACWSD for analysis by their respective contract laboratories as discussed in Section 4.4.

Analytical results from corresponding sample splits for parameters which exhibit detectable concentrations are provided in Table 7.6-1 through 7.6-6. Parameters that exhibit detectable concentrations include DIMP, DBCP, dieldrin, aldrin, fluoride, and chloride. Relative deviations from the mean of detectable concentrations are within 26 percent in all cases, and are generally much lower.

Parameters that were undetectable in all sample splits analyzed include dieldrin, endrin, isodrin, chloroform, carbon tetrachloride, dichloroethylene, trichloroethylene, tetrachloroethylene, and chlorobenzene. A summary of the detection limits attained for each of the compounds analyzed but not detected is provided in Table 7.6-7.

07/11/86

Table 7.6-1. Comparison of DIMP Analytical Results From Corresponding ESE, Shell, CDH, EPA and SACWSD Sample Splits  
(Units in µg/l or ppb)

Sample Designation	ESE	Shell	CDH <sup>1</sup>	EPA	SACWSD
DOM-1	46	40	NA	NA	NA
DOM-3	<10	NA	<0.5	NA	NA
DOM-5	<10	14	NA	NA	NA
DOM-6	<10	<10	NA	NA	NA
DOM-7	40	NA	36	NA	26
DOM-10	<10	NA	NA	<1.0	NA
DOM-11	1600	1500	1000	NA	NA
DOM-12	<10	NA	7.5	NA	NA
DOM-14	<10	NA	<0.5	NA	NA
OTH-5	<10	NA	NA	NA	<10
OTH-9	<10	<10	NA	NA	NA
OTH-12	<10	NA	NA	13	NA
OTH-14	<10	<10	NA	NA	NA
OTH-16	<10	NA	NA	6	NA
OTH-17	<10	<10	NA	NA	NA
OTH-19	<10	<10	NA	<1.0	NA
OTH-22	<10	<10	NA	NA	NA
OTH-27	<10	<10	NA	NA	NA

NA = Not Analyzed.

<sup>1</sup> = Holding Time Exceeded.

Table 7.6-2. Comparison of DBCP Analytical Results From Corresponding ESE, Shell, CDH, and EPA Sample Splits  
(Units in µg/l or ppb)

Sample Designation	ESE	Shell	CDH <sup>1</sup>	EPA
DOM-1	<.13	<0.06	NA	NA
DOM-3	<.13	NA	<0.06	NA
DOM-5	<.13	<0.06	NA	NA
DOM-6	<.13	<0.06	NA	NA
DOM-7	<.13	NA	<0.06	NA
DOM-10	<.13	NA	NA	0.1
DOM-11	<.13	<0.06	<0.06	NA
DOM-12	<.13	NA	<0.06	NA
DOM-14	<.13	NA	<0.06	NA
OTH-5	<.13	NA	NA	NA
OTH-9	<.13	<0.06	NA	NA
OTH-12	<.13	NA	NA	<0.1
OTH-14	<.13	<0.06	NA	NA
OTH-16	NA	NA	NA	<0.1
OTH-17	<.13	<0.06	NA	NA
OTH-19	<.13	<0.06	NA	<0.1
OTH-22	<.13	<0.06	NA	NA
OTH-27	<.13	<0.06	NA	NA

NA = Not Analyzed.

<sup>1</sup> = Holding Time Exceeded.

Table 7.6-3. Comparison of Aldrin Analytical Results from Corresponding ESE, Shell, and EPA Sample Splits  
(Units in  $\mu\text{g/l}$  or ppb)

Sample Designation	ESE	Shell	EPA
DOM-1	<.07	<0.2	NA
DOM-5	<.07	<0.2	NA
DOM-6	.10	<0.2	NA
DOM-10	<.07	NA	<0.05
DOM-11	<.07	<0.2	NA
OTH-9	<.07	<0.2	NA
OTH-12	<.07	NA	<0.05
OTH-14	<.07	<0.2	NA
OTH-16	<.07	NA	<0.05
OTH-17	<.07	<0.2	NA
OTH-19	<.07	<.02	<0.05
OTH-22	<.07	<0.2	NA
OTH-27	<.07	<0.2	NA

NA = Not Analyzed.

Table 7.6-4. Comparison of Dieldrin Analytical Results from Corresponding ESE, Shell, and EPA Sample Splits (Units in  $\mu\text{g/l}$  or ppb)

Sample Designation	ESE	Shell	EPA
DOM-1	<.06	<0.2	NA
DOM-5	<.06	<0.2	NA
DOM-6	<.06	<0.2	NA
DOM-10	<.06	NA	<0.1
DOM-11	<.06	<0.2	NA
OTH-9	<.06	<0.2	NA
OTH-12	<.06	NA	<0.1
OTH-14	<.06	<0.2	NA
OTH-16	<.06	NA	<0.1
OTH-17	<.06	<0.2	NA
OTH-19	<.06	<0.2	<0.1
OTH-22	<0.6	<0.2	NA
OTH-27	.07	<0.2	NA

NA = Not Analyzed.

Table 7.6-5. Comparison of Fluoride Analytical Results From  
Corresponding ESE, EPA and SACWSD Sample Splits  
(Units in mg/l or ppm)

Sample Designation	ESE	EPA	SACWSD
DOM-10	1.9	2.2	NA
OTH-5	<1.2	NA	1.2
OTH-12	1.7	1.8	NA
OTH-16	<1.2	1.2	NA
OTH-19	1.5	1.9	NA

NA = Not Analyzed.



Table 7.6-6. Comparison of Chloride Analytical Results From  
Corresponding ESE, EPA and SACWSD Sample Splits  
(Units in mg/l or ppm)

Sample Designation	ESE	EPA	SACWSD
DOM-10	<4.8	5.1	NA
OTH-5	54	NA	51
OTH-12	300	300	NA
OTH-16	64	62	NA
OTH-19	70	68	NA

NA = Not Analyzed.

Table 7.6-7. Detection Limits and Number of Analyses for Corresponding ESE, Shell, EPA, and SACWSD Determinations Where No Analytes Were Detected (Limits are in µg/l or ppb).

Parameter	ESE		Shell		EPA		SACWSD	
	Limit	Number	Limit	Number	Limit	Number	Limit	Number
Endrin	<0.05	14	<1.0	10	<1.0	4	<0.1	1
Isodrin	<0.06	13	<0.2	10	<0.006	4	NA	NA
Chloroform	<1.4	6	NA	NA	<5.0	4	<5.0	2
Carbon Tetrachloride	<2.4	6	NA	NA	<2.0	4	<5.0	2
Dichloroethylene	<1.2	6	NA	NA	<5.0	4	<5.0	2
Trichloroethylene	<1.1	6	NA	NA	<3.0	4	<5.0	2
Tetrachloroethylene	<1.3	6	NA	NA	<1.0	4	<5.0	2
Chlorobenzene	<0.58	6	NA	NA	<2.0	4	<5.0	2
Total Samples		40		10		4		2

NA = Not Analyzed

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**APPENDIX A**

**CHEMICAL DATA**

07/18/86

PAGE # 1

OFFPOST CONSUMPTIVE USE WELLS PHASE II  
SAMPLES COLLECTED IN FALL 1985

SAMPLE STA ID DATE TIME	39330 ALDRIN (UG/L)	39430 ISODRIN (UG/L)	39380 DIELDRIN (UG/L)	39390 ENDRIN (UG/L)	77985 DCPD (UG/L)	99133 DBCP (NEMAGON) (UG/L)	98551 DIMP (UG/L)	34546 T12DCE (UG/L)	32106 CHCL3 (UG/L)	32102 CCL4 (UG/L)
559900 DOM-1 10/02/85 1024	<0.07	<0.06	<0.06	<0.05	<9.31	<0.13	46	<1.20	<1.40	<2.40
559902 DOM-3 10/03/85 1225	<0.07	<0.06	<0.06	<0.05	<9.31	<0.13	<10	<1.20	<1.40	<2.40
559903 DOM-4 09/30/85 1310	<0.07	<0.06	<0.06	<0.05	<9.31	<0.13	<10	<1.20	<1.40	<2.40
559904 DOM-5 10/01/85 855	<0.07	<0.06	<0.06	<0.05	<9.31	<0.13	<10	<1.20	<1.40	<2.40
559905 DOM-6 10/01/85 1010	0.1	<0.06	<0.06	<0.05	<9.31	<0.13	<10	<1.20	<1.40	<2.40
559906 DOM-7 10/03/85 1025	<0.07	<0.06	<0.06	<0.05	<9.31	<0.13	40	<1.20	<1.40	<2.40
559907 DOM-8 10/10/85 920	<0.07	<0.06	<0.06	<0.05	<9.31	<0.13	<10	<1.20	<1.40	<2.40
559908 DOM-9 10/01/85 1130	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
559909 DOM-10 10/07/85 1030	<0.07	<0.06	<0.06	<0.05	<9.31	<0.13	<10	<1.20	<1.40	<2.40
559910 DOM-11 10/01/85 1145	<0.07	<0.06	<0.06	<0.05	<9.31	<0.13	1600	<1.20	<1.40	<2.40
559911 DOM-12 10/04/85 845	<0.07	<0.06	<0.06	<0.05	<9.31	<0.13	<10	<1.20	<1.40	<2.40
559913 DOM-14 09/30/85 1056	<0.07	<0.06	<0.06	<0.05	<9.31	<0.13	<10	<1.20	<1.40	<2.40
559914 DOM-15 10/09/85 916	<0.07	<0.06	<0.06	<0.05	<9.31	<0.13	<10	<1.20	<1.40	<2.40
559920 OTH-1 10/10/85 1225	<0.07	<0.06	<0.06	<0.05	<9.31	<0.13	12	<1.20	<1.40	<2.40
559921 OTH-2 10/03/85 1140	<0.07	<0.06	<0.06	<0.05	<9.31	<0.13	47	<1.20	<1.40	<2.40
559922 OTH-3 10/10/85 1130	<0.07	<0.06	<0.06	<0.05	<9.31	<0.13	<10	<1.20	<1.40	<2.40
559923 OTH-4 10/09/85 1235	<0.07	<0.06	<0.06	<0.05	<9.31	<0.13	40	<1.20	<1.40	<2.40
559924 OTH-5 10/03/85 915	<0.07	<0.06	<0.06	<0.05	<9.31	<0.13	<10	<1.20	<1.40	<2.40
559925 OTH-6 10/11/85 1330	<0.07	<0.06	<0.06	<0.05	<9.31	<0.13	<10	<1.20	<1.40	<2.40
559926 OTH-7 10/11/85 1110	<0.07	<0.06	<0.06	<0.05	<9.31	<0.13	58	<1.20	<1.40	<2.40
559927 OTH-8 10/09/85 1415	<0.07	<0.06	<0.06	<0.05	<9.31	<0.13	86	<1.20	<1.40	<2.40
559928 OTH-9 10/01/85 1448	<0.07	<0.06	<0.06	<0.05	<9.31	<0.13	<10	<1.20	<1.40	<2.40
559929 OTH-10 10/04/85 950	<0.07	<0.06	<0.06	<0.05	<9.31	<0.13	54	<1.20	<1.40	<2.40
559930 OTH-11 10/11/85 910	<0.07	<0.06	<0.06	<0.05	<9.31	<0.13	<10	<1.20	<1.40	<2.40
559931 OTH-12 10/07/85 1130	<0.07	<0.06	<0.06	<0.05	<9.31	<0.13	<10	<1.20	<1.40	<2.40
559932 OTH-13 10/03/85 1300	<0.07	<0.06	<0.06	<0.05	<9.31	<0.13	73	<1.20	<1.40	<2.40
559933 OTH-14 10/02/85 1600	<0.07	<0.06	<0.06	<0.05	<9.31	<0.13	<10	<1.20	<1.40	<2.40
559934 OTH-15 10/01/85 1300	<0.07	<0.06	<0.06	<0.05	<9.31	<0.13	<10	<1.20	<1.40	<2.40
559935 OTH-16 10/07/85 920	<0.07	<0.06	<0.06	<0.05	<9.31	<0.13	25	<1.20	<1.40	<2.40
559936 OTH-17 09/30/85 1205	<0.07	<0.06	<0.06	<0.05	NA	NA	<10	<1.20	<1.40	<2.40
559937 OTH-18 10/07/85 1245	<0.07	<0.06	<0.06	<0.05	<9.31	<0.13	<10	<1.20	<1.40	<2.40
559938 OTH-19 09/30/85 930	<0.07	<0.06	<0.06	<0.05	<9.31	<0.13	<10	<1.20	<1.40	<2.40
559939 OTH-20 10/07/85 1510	<0.07	<0.06	<0.06	<0.05	<9.31	<0.13	<10	<1.20	<1.40	<2.40
559941 OTH-22 10/02/85 1420	<0.07	<0.06	<0.06	<0.05	<9.31	<0.13	<10	<1.20	<1.40	<2.40
559942 OTH-23 10/8/85 910	<0.07	<0.06	0.9	0.8	25.2	<0.13	210	<1.20	<1.40	<2.40
559943 OTH-24 10/11/85 810	<0.07	<0.06	<0.06	<0.05	<9.31	<0.13	150	<1.20	<1.40	<2.40
559944 OTH-25 10/09/85 1030	<0.07	<0.06	<0.06	<0.05	<9.31	<0.13	<10	<1.20	<1.40	<2.40
559946 OTH-27 10/02/85 1230	<0.07	<0.06	0.07	<0.05	<9.31	<0.13	<10	<1.20	<1.40	<2.40
559947 OTH-28 10/10/85 955	<0.07	<0.06	<0.06	<0.05	<9.31	<0.13	48	<1.20	<1.40	<2.40
559948 OTH-29 10/04/85 1335	<0.07	<0.06	<0.06	<0.05	<9.31	<0.13	44	<1.20	<1.40	<2.40
559949 OTH-30 10/8/85 1010	<0.07	<0.06	<0.06	<0.05	<9.31	<0.13	13	<1.20	<1.40	<2.40
559950 OTH-16 10/07/85 920	NA	NA	NA	NA	<9.31	<0.13	NA	NA	NA	NA

07/18/86

PAGE # 2

# OFFPOST CONSUMPTIVE USE WELLS PHASE II SAMPLES COLLECTED IN FALL 1985

SAMPLE STA ID	DATE	TIME	39180 TRCLE (UG/L)	34475 TCLEE (UG/L)	34301 CLC6H5 (UG/L)	98555 CHLORIDE (UG/L)	98556 FLUORIDE (UG/L)	71999 SAMPLE TYPE	72005 SAMPLE TECHN	99758 SAMPLE DEPTH (CM)	99759 SITE TYPE	99720 INSTAL CODE
559900 DOM-1	10/02/85	1024	<1.1	<1.3	<0.58	157000	<1200	GW	G	914	WELL	RK
559902 DOM-3	10/03/85	1225	<1.1	<1.3	<0.58	117000	<1200	GW	G	1220	WELL	RK
559903 DOM-4	09/30/85	1310	<1.1	<1.3	<0.58	85400	<1200	GW	G	1070	WELL	RK
559904 DOM-5	10/01/85	855	<1.1	<1.3	<0.58	83400	<1200	GW	G	1220	WELL	RK
559905 DOM-6	10/01/85	1010	<1.1	<1.3	<0.58	60300	<1200	GW	G	100000	WELL	RK
559906 DOM-7	10/03/85	1025	<1.1	<1.3	<0.58	76400	<1200	GW	G	1830	WELL	RK
559907 DOM-8	10/10/85	920	<1.1	<1.3	<0.58	<4800	3580	GW	G	100000	WELL	RK
559908 DOM-9	10/01/85	1130	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
559909 DOM-10	10/07/85	1030	<1.1	<1.3	<0.58	<4800	1920	GW	G	100000	WELL	RK
559910 DOM-11	10/01/85	1145	<1.1	<1.3	<0.58	626000	1510	GW	G	100000	WELL	RK
559911 DOM-12	10/04/85	845	<1.1	<1.3	<0.58	102000	1710	GW	G	100000	WELL	RK
559913 DOM-14	09/30/85	1056	<1.1	<1.3	<0.58	<4800	1960	GW	G	2900	WELL	RK
559914 DOM-15	10/09/85	916	<1.1	<1.3	<0.58	<4800	1610	GW	G	975	WELL	RK
559920 OTH-1	10/10/85	1225	<1.1	<1.3	<0.58	128000	1390	GW	G	1070	WELL	RK
559921 OTH-2	10/03/85	1140	<1.1	<1.3	<0.58	139000	<1200	GW	P	610	WELL	RK
559922 OTH-3	10/10/85	1130	<1.1	<1.3	<0.58	133000	1290	GW	G	366	WELL	RK
559923 OTH-4	10/09/85	1235	<1.1	<1.3	<0.58	106000	1250	GW	P	1650	WELL	RK
559924 OTH-5	10/03/85	915	<1.1	<1.3	<0.58	54100	<1200	GW	G	100000	WELL	RK
559925 OTH-6	10/11/85	1330	<1.1	<1.3	<0.58	91200	1420	GW	P	1400	WELL	RK
559926 OTH-7	10/11/85	1110	<1.1	<1.3	<0.58	190000	1760	GW	P	640	WELL	RK
559927 OTH-8	10/09/85	1415	<1.1	<1.3	<0.58	119000	<1200	GW	P	1490	WELL	RK
559928 OTH-9	10/01/85	1448	<1.1	<1.3	<0.58	211000	1390	GW	P	357	WELL	RK
559929 OTH-10	10/04/85	950	<1.1	<1.3	<0.58	160000	1690	GW	P	362	WELL	RK
559930 OTH-11	10/11/85	910	<1.1	<1.3	<0.58	246000	1690	GW	G	914	WELL	RK
559931 OTH-12	10/07/85	1130	<1.1	<1.3	<0.58	302000	1740	GW	G	1620	WELL	RK
559932 OTH-13	10/03/85	1300	<1.1	<1.3	<0.58	98300	1390	GW	P	1680	WELL	RK
559933 OTH-14	10/02/85	1600	<1.1	<1.3	<0.58	99300	1360	GW	P	1180	WELL	RK
559934 OTH-15	10/01/85	1300	<1.1	<1.3	<0.58	89100	<1200	GW	P	1370	WELL	RK
559935 OTH-16	10/07/85	920	<1.1	<1.3	<0.58	63600	<1200	GW	G	1220	WELL	RK
559936 OTH-17	09/30/85	1205	<1.1	<1.3	<0.58	35500	<1200	GW	G	1370	WELL	RK
559937 OTH-18	10/07/85	1245	<1.1	<1.3	<0.58	130000	1500	GW	G	1520	WELL	RK
559938 OTH-19	09/30/85	930	<1.1	<1.3	<0.58	70500	1460	GW	G	100000	WELL	RK
559939 OTH20	10/07/85	1510	<1.1	<1.3	<0.58	35900	1420	GW	P	1430	WELL	RK
559941 OTH-22	10/02/85	1420	<1.1	<1.3	<0.58	158000	1510	GW	P	1220	WELL	RK
559942 OTH-23	10/08/85	910	<1.1	10	<0.58	308000	2520	GW	P	321	WELL	RK
559943 OTH-24	10/11/85	810	<1.1	<1.3	<0.58	152000	1250	GW	G	100000	WELL	RK
559944 OTH-25	10/09/85	1030	<1.1	<1.3	<0.58	82800	1300	GW	P	811	WELL	RK
559946 OTH-27	10/02/85	1230	<1.1	<1.3	<0.58	145000	1510	GW	G	100000	WELL	RK
559947 OTH-28	10/10/85	955	<1.1	<1.3	<0.58	171000	1660	GW	P	488	WELL	RK
559948 OTH29	10/04/85	1335	<1.1	<1.3	<0.58	114000	1280	GW	G	1520	WELL	RK
559949 OHT30	10/08/85	1010	<1.1	<1.3	<0.58	83600	<1200	GW	G	100000	WELL	RK
559950 OTH-16	10/07/85	920	NA	NA	NA	NA	NA	GW	G	1220	WELL	RK

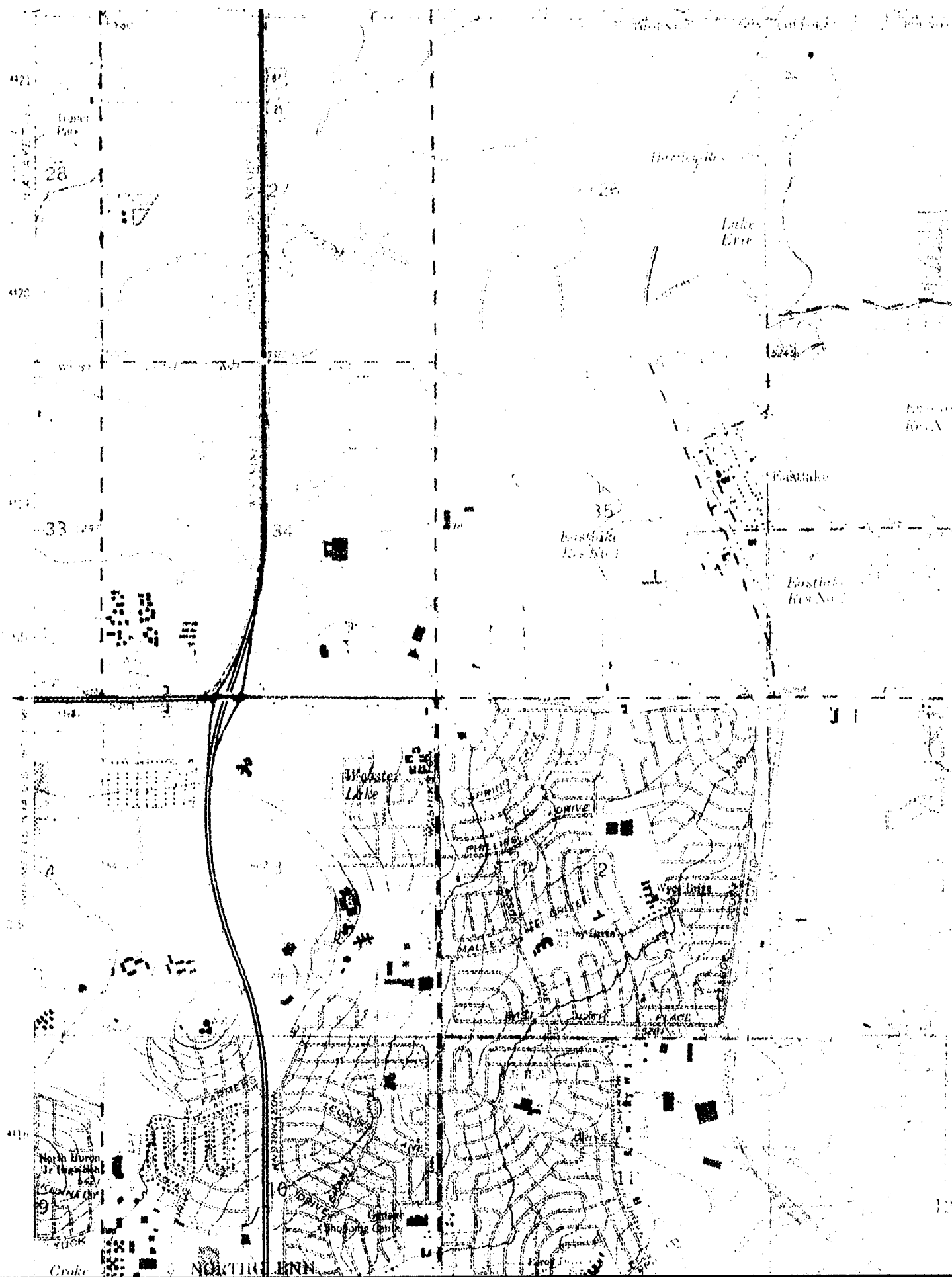
07/18/86

PAGE # 3

OFFPOST CONSUMPTIVE USE WELLS PHASE II  
SAMPLES COLLECTED IN FALL 1985

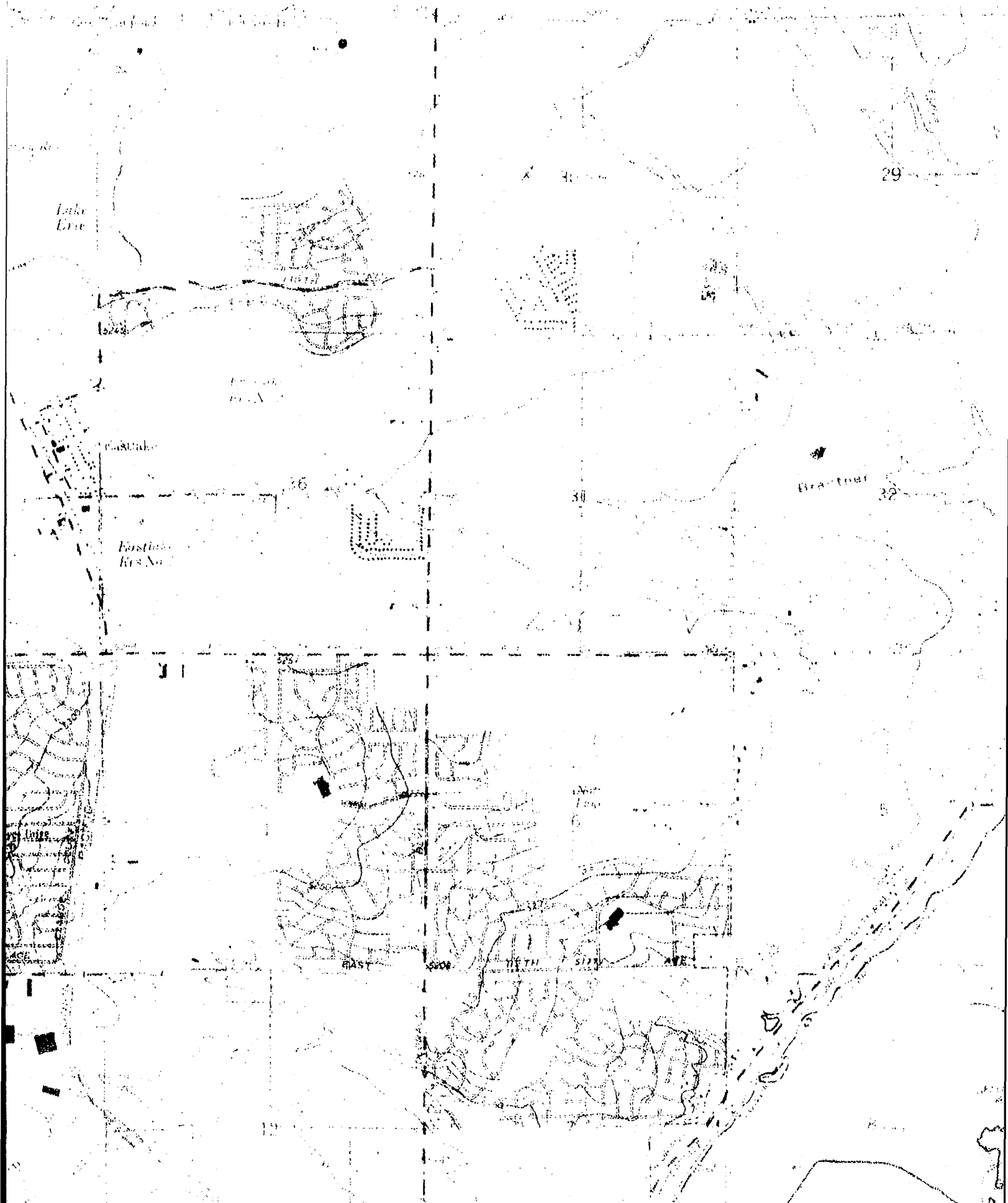
SAMPLE STA ID	DATE	TIME	400 PH	94 FIELD CONDUCT.
			(SU)	UMHOS/CM
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559902 DOM-3	10/03/85	1225	7.05	1180
559903 DOM-4	09/30/85	1310	7.28	1210
559904 DOM-5	10/01/85	855	7.37	1140
559905 DOM-6	10/01/85	1010	7.50	728
559906 DOM-7	10/03/85	1025	7.38	1010
559907 DOM-8	10/10/85	920	8.65	656
559908 DOM-9	10/01/85	1130	NA	NA
559909 DOM-10	10/07/85	1030	8.56	388
559910 DOM-11	10/01/85	1145	7.11	3010
559911 DOM-12	10/04/85	845	7.32	1020
559913 DOM-14	09/30/85	1056	8.97	403
559914 DOM-15	10/09/85	916	7.45	403
559920 OTH-1	10/10/85	1225	7.18	1290
559921 OTH-2	10/03/85	1140	6.94	1280
559922 OTH-3	10/10/85	1130	7.06	1240
559923 OTH-4	10/09/85	1235	6.77	1240
559924 OTH-5	10/03/85	915	6.94	987
559925 OTH-6	10/11/85	1330	7.12	1100
559926 OTH-7	10/11/85	1110	7.20	1660
559927 OTH-8	10/09/85	1415	6.60	1280
559928 OTH-9	10/01/85	1448	6.99	1610
559929 OTH-10	10/04/85	950	7.21	1490
559930 OTH-11	10/11/85	910	7.18	1730
559931 OTH-12	10/07/85	1130	6.75	2220
559932 OTH-13	10/03/85	1300	7.23	1280
559933 OTH-14	10/02/85	1600	7.38	908
559934 OTH-15	10/01/85	1300	7.38	1060
559935 OTH-16	10/07/85	920	7.37	1920
559936 OTH-17	09/30/85	1205	6.98	692
559937 OTH-18	10/07/85	1245	6.93	1220
559938 OTH-19	09/30/85	930	7.39	1050
559939 OTH20	10/07/85	1510	6.96	642
559941 OTH-22	10/02/85	1420	7.63	1730
559942 OTH-23	10/08/85	910	7.34	2600
559943 OTH-24	10/11/85	810	7.29	1510
559944 OTH-25	10/09/85	1030	6.71	1040
559946 OTH-27	10/02/85	1230	7.15	1180
559947 OTH-28	10/10/85	955	7.24	1650
559948 OTH29	10/04/85	1335	7.10	1300
559949 OHT30	10/08/85	1010	7.60	1130
559950 OTH-16	10/07/85	920	7.37	1920



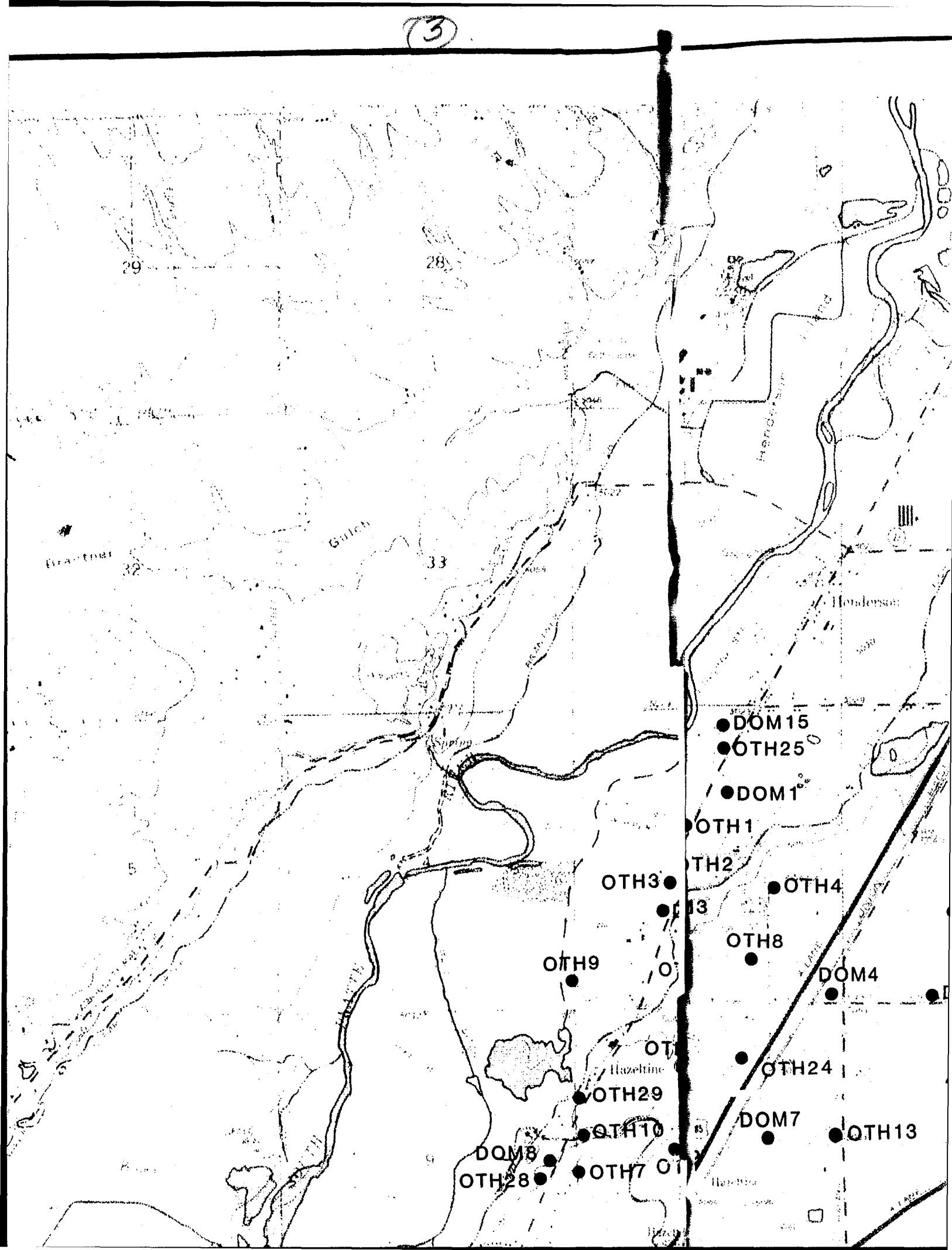


R 68 W

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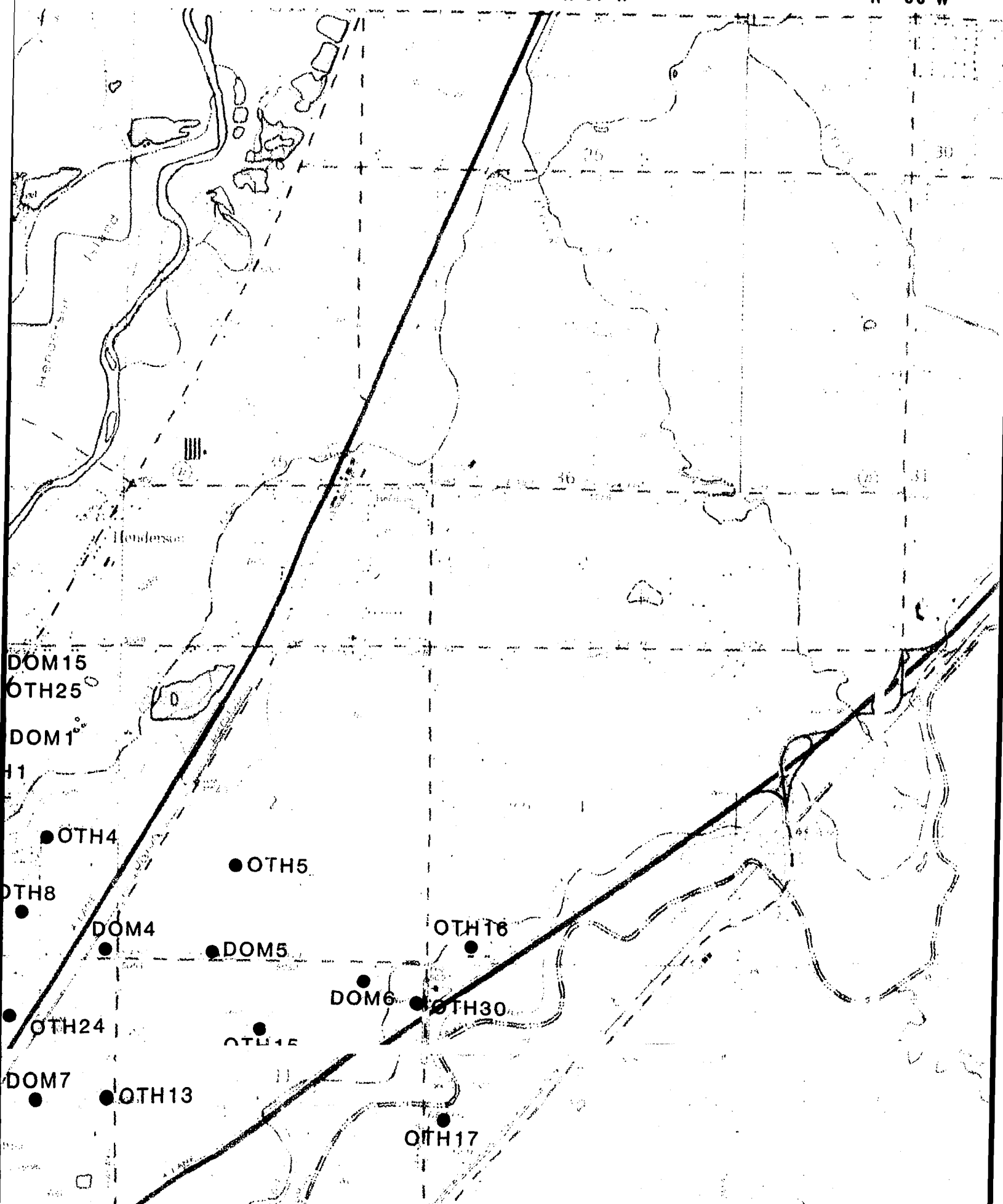
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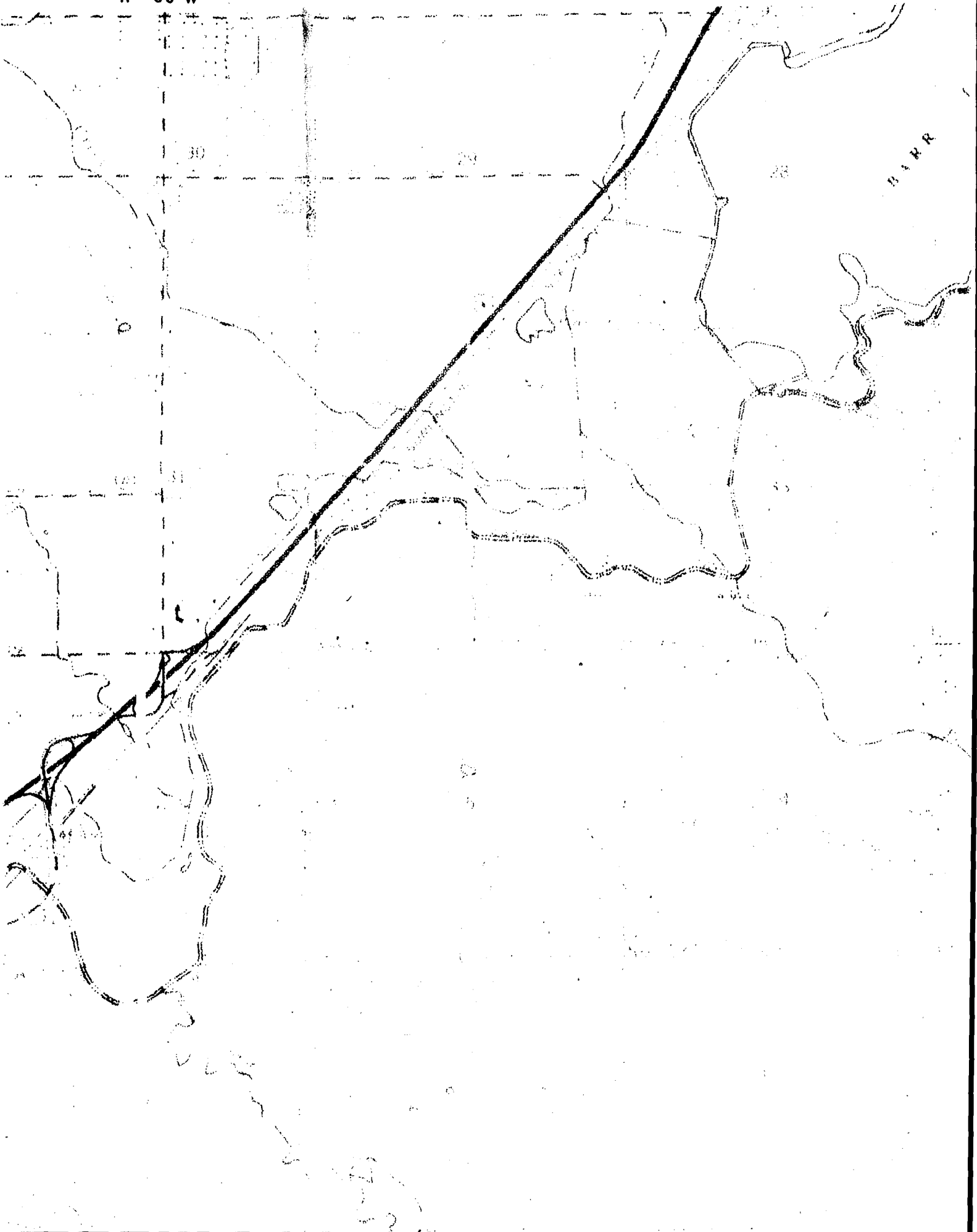
R 67 W

R 66 W



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R 66 W

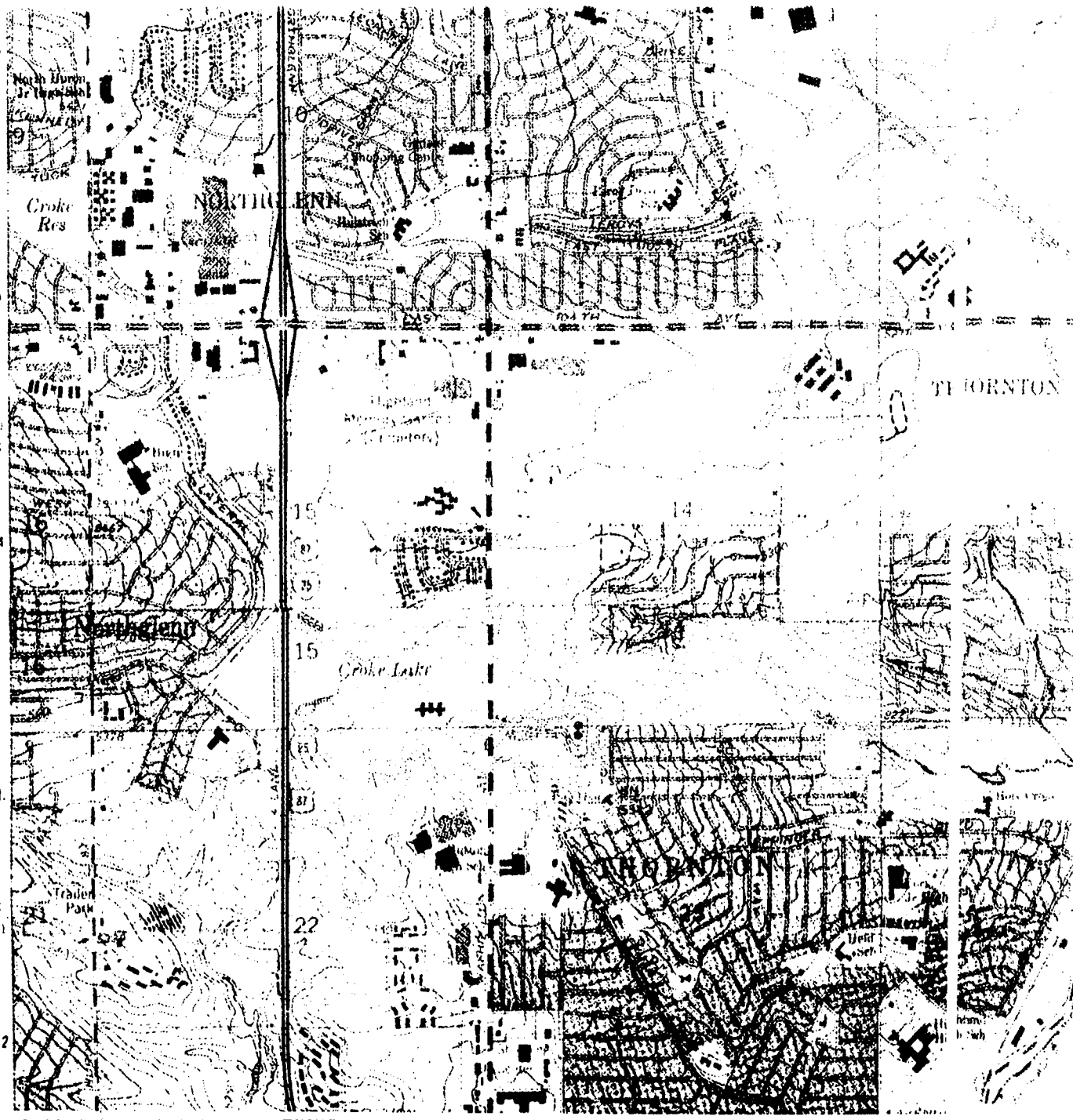


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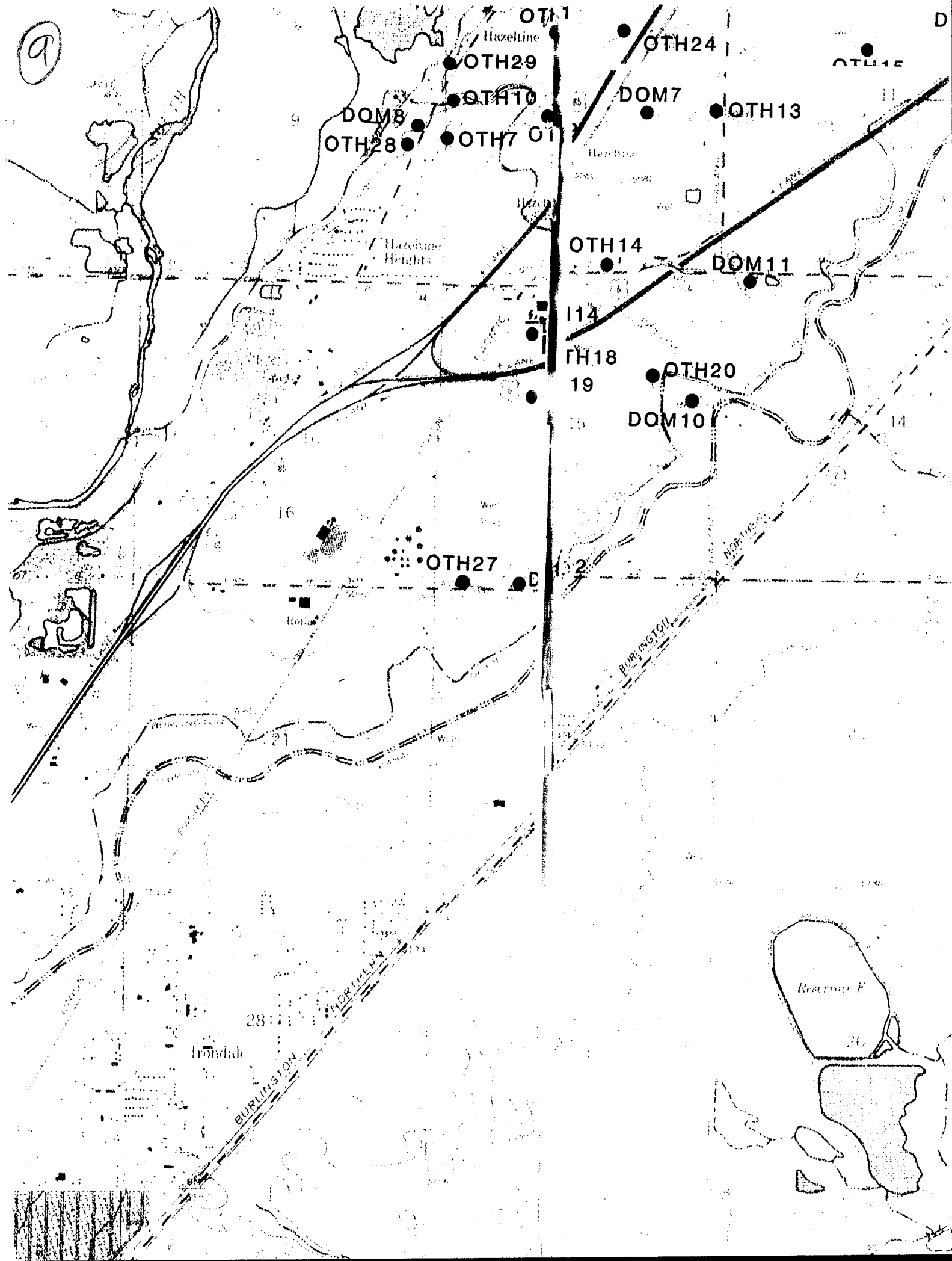
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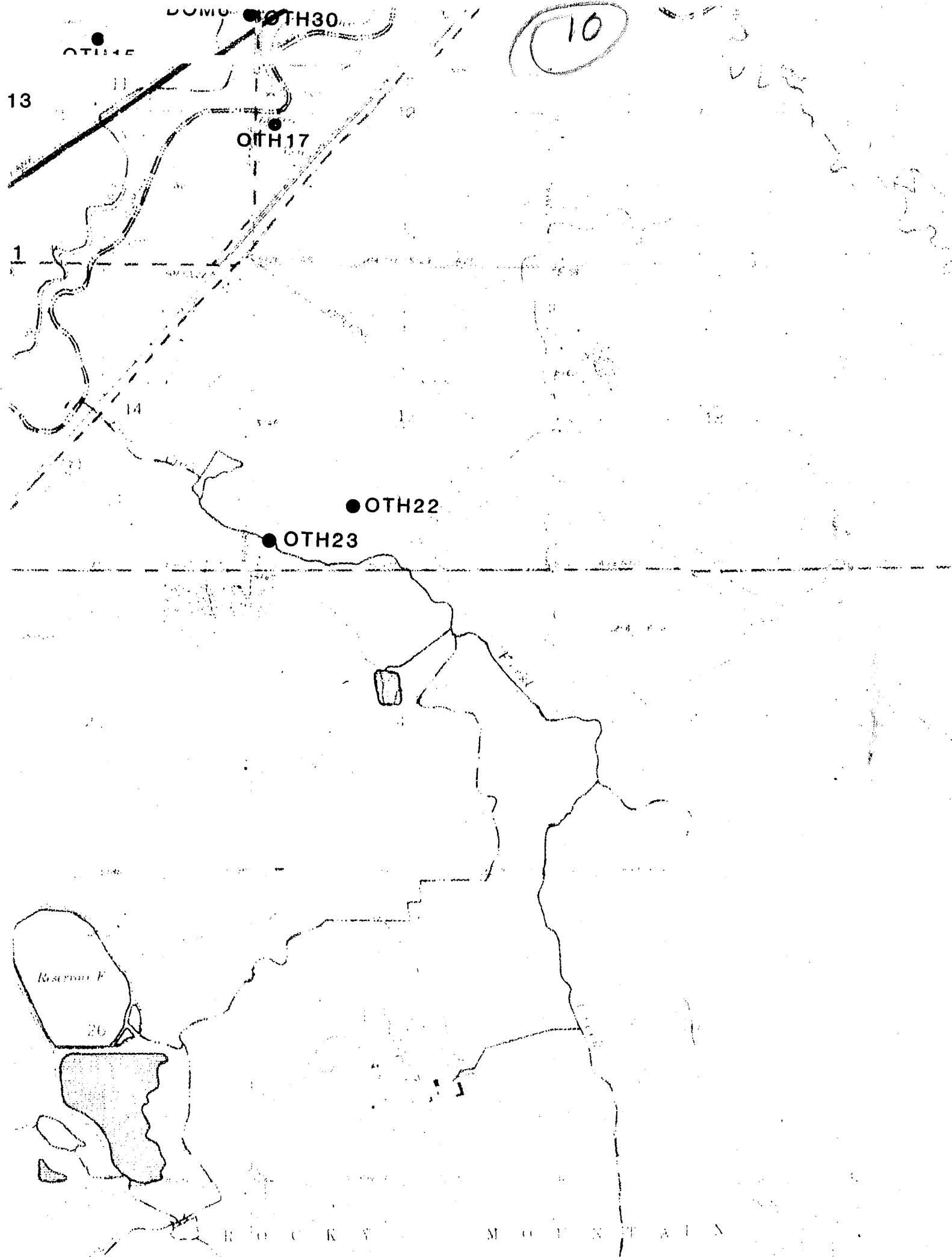
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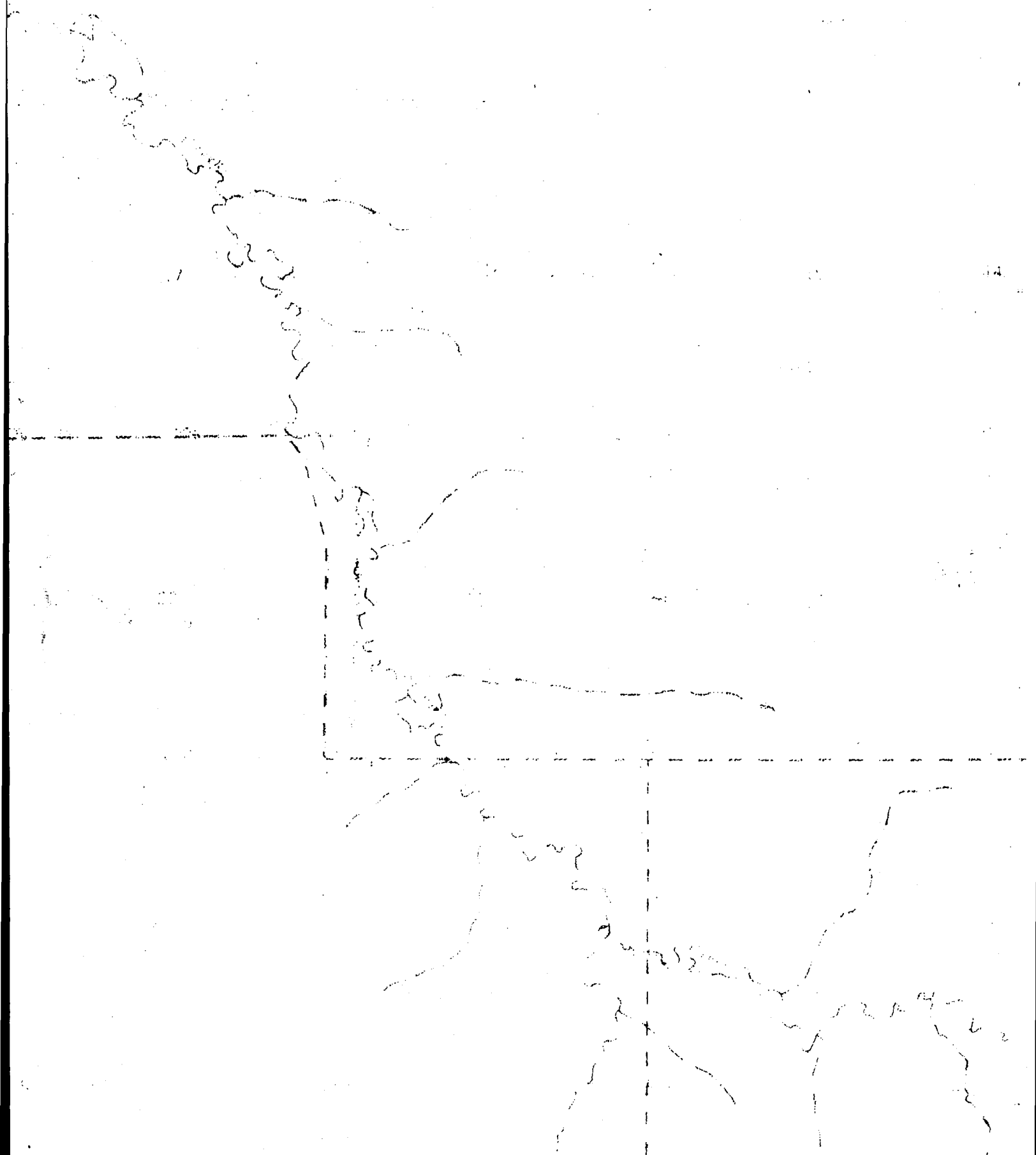
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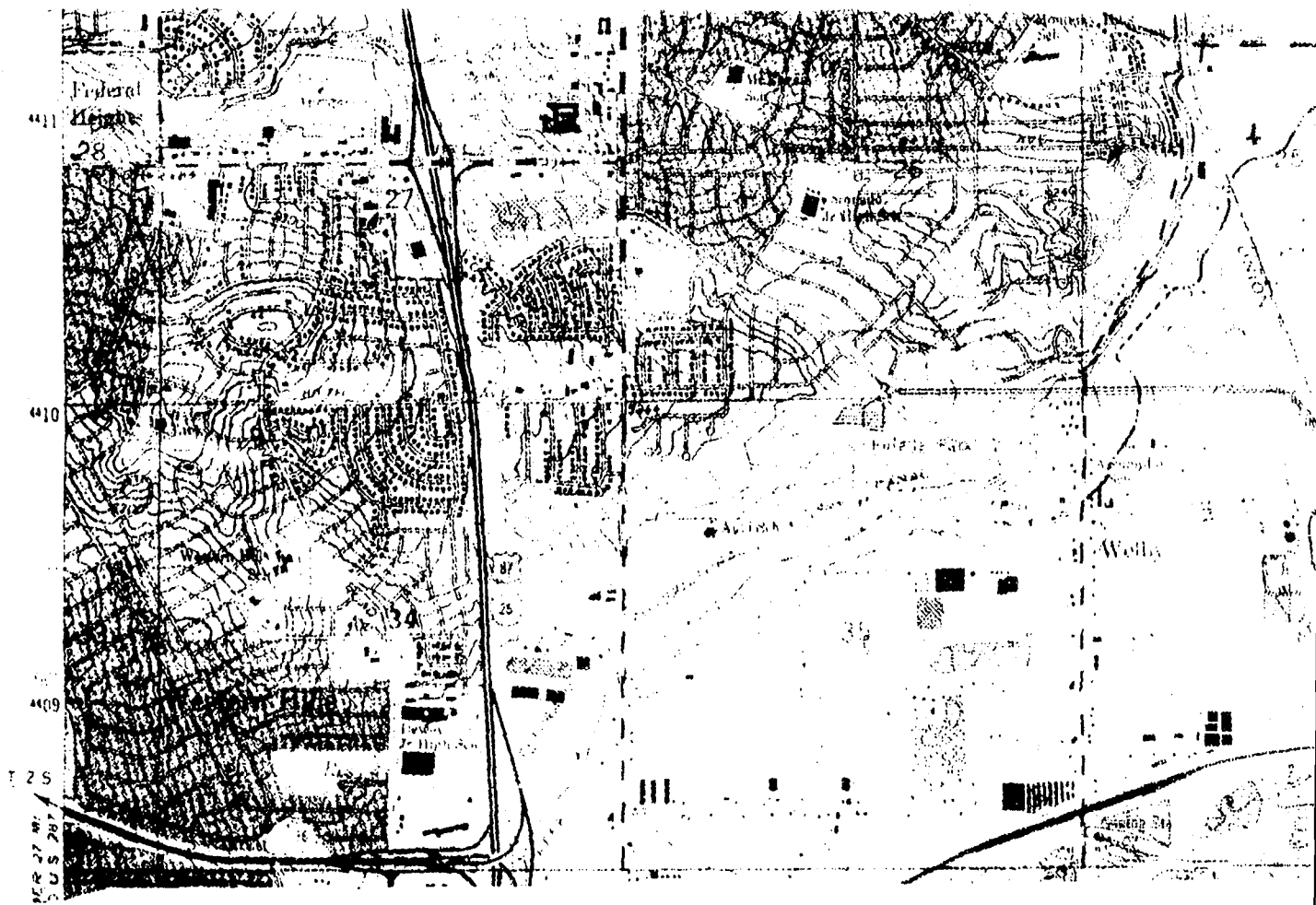




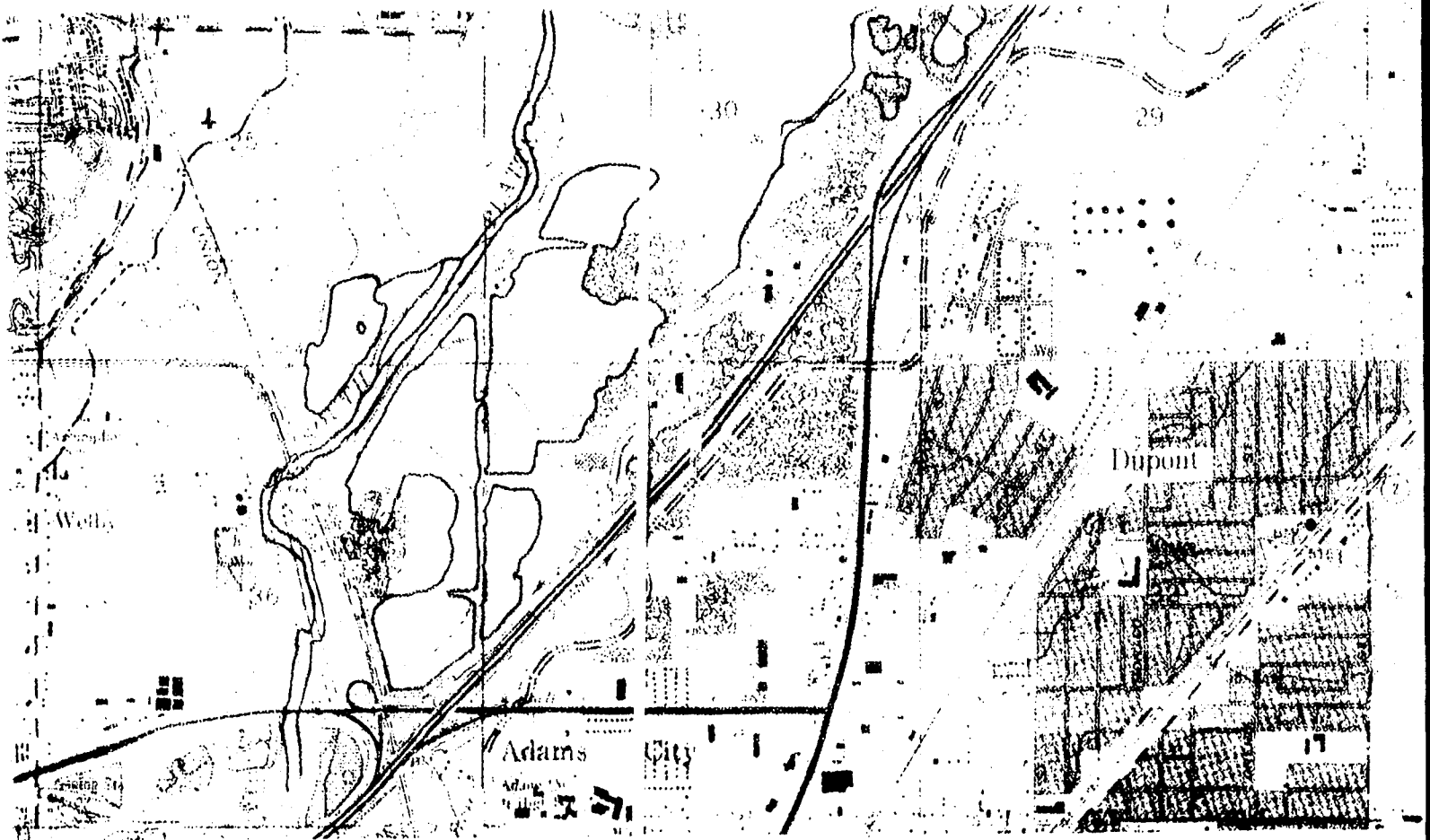


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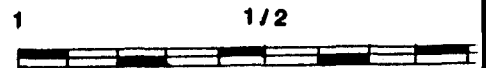




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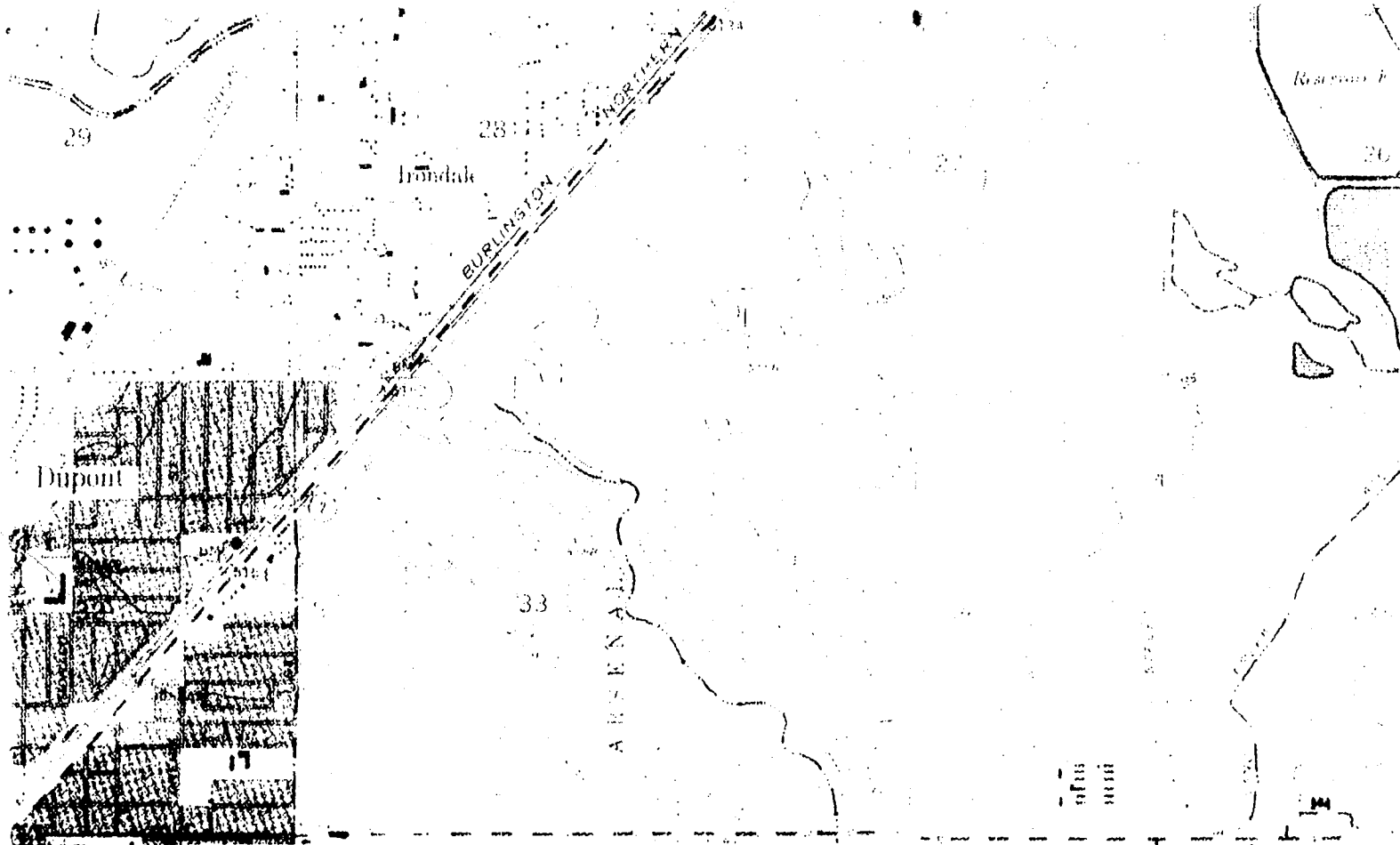
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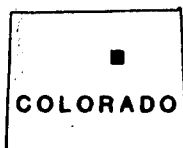
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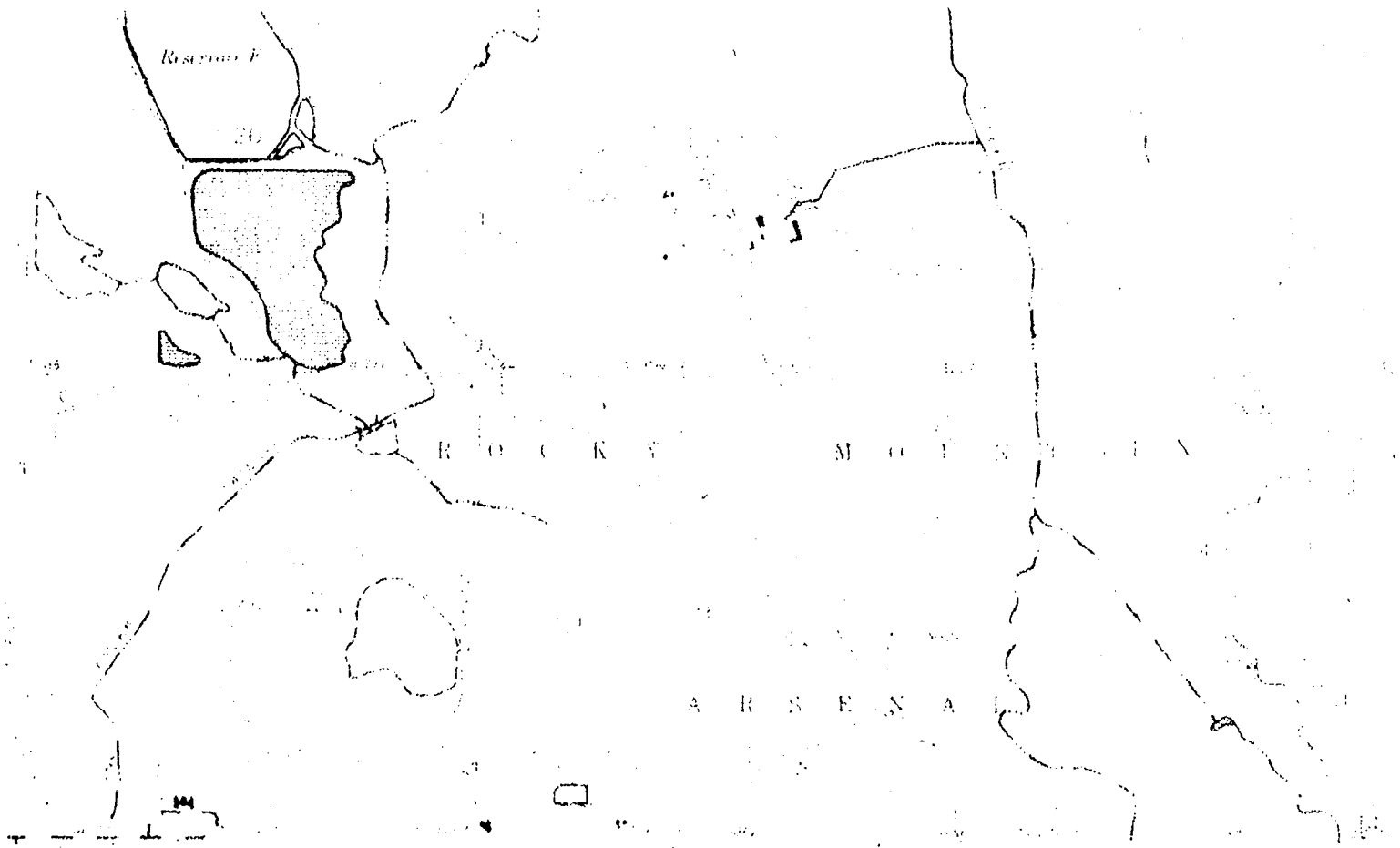
NATIONAL GEODETIC VERTICAL DATUM OF 1929



QUADRANGLE LOCATION



14



13

SOURCE: USGS, BRIGHTON, CO., 1979, COMMERCE, CO., 1980,  
EASTLAKE, CO., 1980, & SABLE, CO., 1979

**PLATE 1**

**84611-001**

**PHASE II CONSUMPTIVE USE WELL LOCATIONS**

DRAWING NO.

DRAWING TITLE

**NO. 84611-1000-1790**

**1:24,000**

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DRAWN/REVISED

J.L.

BY

G.W.T.

CHK'D

7/86

DATE

Prepared for:  
U.S. Army Program Manager's  
For Rocky Mountain Arsenal  
Aberdeen Proving Ground, Maryland

**ESE ENVIRONMENTAL  
AND ENGINEERING**  
AN RSH COMPANY

PROJECT MANAGER: R. Tra

APPROVED FOR ISSUE

16



RCE: USGS, BRIGHTON, CO., 1979, COMMERCE, CO., 1980,  
FLAKE, CO., 1980, & SABLE, CO., 1979

FILE LOCATION: 0P-1

ATE 1  
ASE II CONSUMPTIVE USE WELL LOCATIONS

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ER SCALE

Prepared for:  
U.S. Army Program Manager's Office  
For Rocky Mountain Arsenal  
Aberdeen Proving Ground, Maryland

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AND ENGINEERING, INC.  
AN RSH COMPANY

RPT.

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BY CHK'D DATE

PROJECT MANAGER: R. Traylor

APPROVED FOR ISSUE BY

DATE

17